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Water management of the Upper Comoé river basin, Burkina Faso

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Outlines

Abbreviations and acronyms	
CILSS	Comité Inter-Etats de Lutte contre la Sécheresse dans le Sahel
DADI	Direction de l'Aménagement et du Développement de l'Irrigation from MAHRH
DGGR	Direction Générale du Génie Rural ;
DGPSA	Direction Générale des Prévisions et de la Statistique Agricoles
DGRE	Direction Générale des Ressources en Eau
DGRH	Direction Générale des Ressources Halieutiques
DMN	Direction de la Météorologie Nationale
DRAHRH	Directions Régionales de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques
DPAHRHC	Directions provinciale de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques de la Comoé
IGB	National Geographical Institute (Institut Géographique du Burkina Faso)
INSD	Institut National de la Statistique et la Démographie
IWMI	International Water Management Institute
IWRM	Integrated water resources management
MAHRH	Ministère de l'Agriculture, de l'Hydraulique et des Ressources Halieutiques
ONEA	Office National de l'Eau et de l'Assainissement
ORSTOM	Previous institute of scientific research for development (Office de la Recherche Scientifique et Technique Outre-Mer), now IRD
WAIPRO	West Africa Irrigation Project

Note : This version was controlled by Hervé Lévite (WAIPRO project manager) in July 2010. However this report could be subject to further review by IWMI.

1. Introduction

This study was realised for the West Africa Irrigation Project (WAIPRO). WAIPRO is a research action project implemented in Niger and Burkina Faso by the International Water Management Institute (IWMI) in partnership with the Comité Inter Etats de Lutte contre la sécheresse au Sahel (CILSS). The project is funded by the US-AID.

The project's vision is to enhance the capacity utilization of existing irrigation systems, increase irrigated crop yields, increase farmers' income, reduce farmers' vulnerability to droughts, reduce consumers' vulnerability to current food price hike, and enhance national governments foreign exchange reserve through boosting domestic rice production and sustain water management.

In Burkina Faso, the project is implemented by the Direction des Amenagements et du Developpement de l'Irrigation (DADI) from the « Ministère de l'Agriculture et de l'Hydraulique et des Ressources Halieutiques (MAHRH) ». WAIPRO project aims to assist the three irrigation schmes: Mogtedo, Talembika and Karfiguéla.

This study will be part of activities concerning the Karfiguela irrigation scheme. WAIPRO aims to conduct rehabilitation work on this scheme, to do so, an economic and a technical rapid diagnosis (PRDA) was realised. This study will complement these diagnoses by analysing the context of water management at the sub-catchment level (the upper part of the Comoé River Basin) in order to ensure that the rehabilitation work will increase the chances of a sustainable development of the Karfiguela Irrigation scheme.

Table 1 shows how the study will contribute to answer some of the objectives and activities described in the WAIPRO logframe.

Table 1: Contributions of the study to the WAIPRO logframe

Objectives	Activties	Contributions
1: Participatory analysis of constraints and opportunities of existing irrigation schemes	1.1. Participatory rapid diagnosis and action planning for irrigated agricultural systems	Yes, it complements the diagnosis
	1.2: Performance benchmarking	
	1.3: Analysis of the productivity and profitability of irrigated rice and vegetables	No
Objective 2: Implementation of interventions to improve productivity and performance of irrigation schemes	2.1: Improving water conveyance and distribution and management at the plot level	No
	2.2: Strengthening water users associations	Yes, by reinforcing the CLE and assessing the way to reinforce the position of the UCEPAK in the CLE negotiations
	2.3: Participatory on-farm fertilizer trials to refine recommendations	No
	2.4: Participatory variety adaptation-cum-demonstration trials	No
Objective 3: Capacity building, synthesis, and knowledge sharing	3.1 Enhancing linkages with support services	Yes, the reinforcement of the UCEPAK capacity to negotiate should provide a common basis for discussion and ease exchanges on technical issues
	3.2: Dissemination, synthesis, dissemination and communication	Yes, dissemination of results
	3.3: Workshops	No
	4.1 Ensure the general coordination of WAIPRO	No
	4.1: Coordination of implementation, monitoring and evaluation of the project	Yes, could ensure that the rehabilitation works are effective thanks to the fact that the "water rights" are ensured
Objective 4.2 Support the development of small scale irrigation in the Sahel	4.2.1: Inventory and policy analysis	Yes, contributes to analyse the institutional framework in place in the Comoé
	4.2.2: To review the PRADPIS Programme in order to incorporate the small-scale irrigation priority	No
	4.2.3.: To identify, analyze and disseminate best practices as regards water control for small-scale irrigation in the two project countries	No

1.1. Objectives

The objectives of the study were to:

1. Review and analyse the existing literature related to the land and water management of the study area.
2. Consult with stakeholders and carry out supplementary field data collection as needed to understand the issues and challenges related to water management in the study area.
3. Identify existing data and tools and their potential use for improving decisions related to water management by the Technical Committee CLE of the Upper Comoé.
4. Collect and examine the possibilities of (re)use of existing data and decision-support tools, identify missing data and information, and the means necessary for their collection.
5. Assess possibilities of negotiating improved water rights (quantity and temporal availability) for the Karfiguela irrigation scheme

This report is based on a review of existing literature, two field visits when some interviews were held with local managers, water users and farmers. There have been a number of projects and studies conducted in the case study area because of its particular natural and economic and social characteristics. The literature reviewed is mainly composed of projects and studies reports concerning the management and development of the three dams and more generally concerning the management of water resources in the system. Several reports were written as part or following the research work achieved by the University of Georgia and the Tuft University on the modelling and development of two Decision Support Tools. There are as well some reports produced by the ministries in charge of agriculture and of economics and development. The literature reviewed is listed in the bibliography.

1.2 Outlines of the report

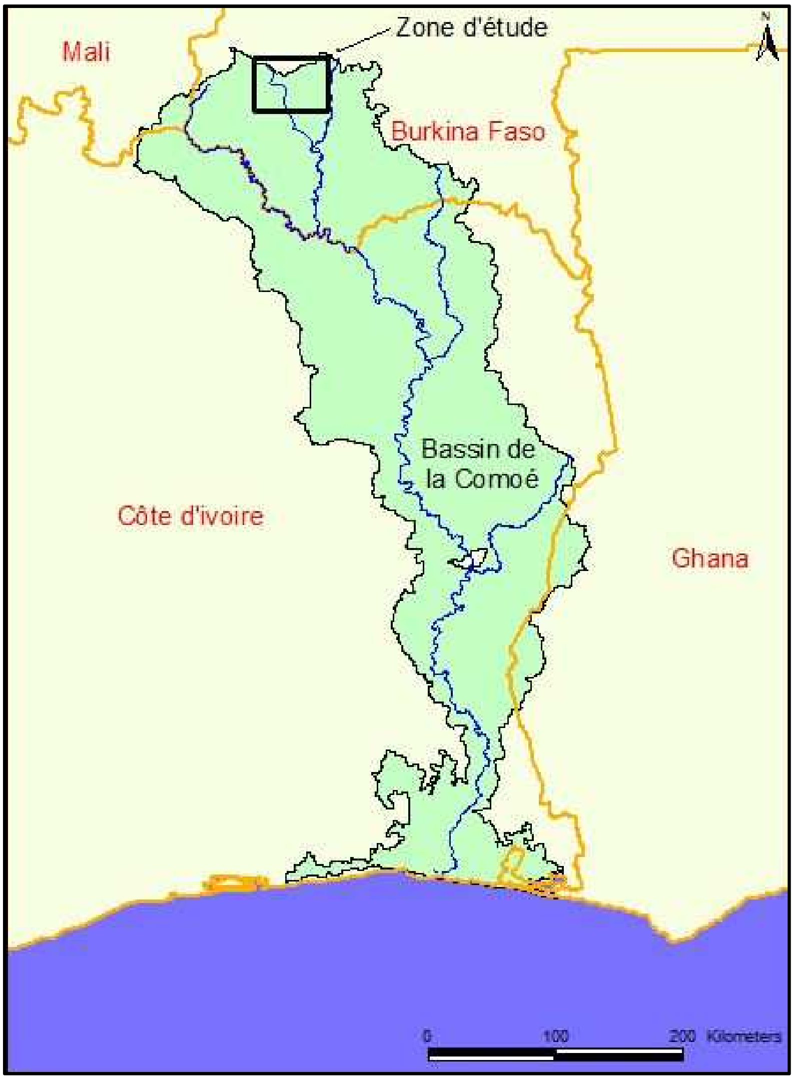
The report first presents a description of the context of the study area and of the main issues and challenges based on the review of the existing literature. The second section presents the water management tools and their potential uses that were identified, a special attention is given to two Decision Support Tools that were developed by a research action project to assist the management of the dams and the allocation of water resources by the local water management platform called CLE. The third section is a short review of the existing and missing data and information that would be required to assist the management of water resources by the CLE. The last section presents an assessment of the means that could reinforce the negotiation of better “water rights” for the Karfiguela Irrigation scheme.

2. Water Management in the study area

2.1 Generalities

The study area is located in the northern part of the Upper Comoé River basin which is a sub-basin of the Comoé river basin. The Comoé river originates in Burkina Faso, forms the border between Burkina Faso and Côte d'Ivoire, then flows through Ivory Cost up the ocean into the Gulf of Guinea (see figure 1).

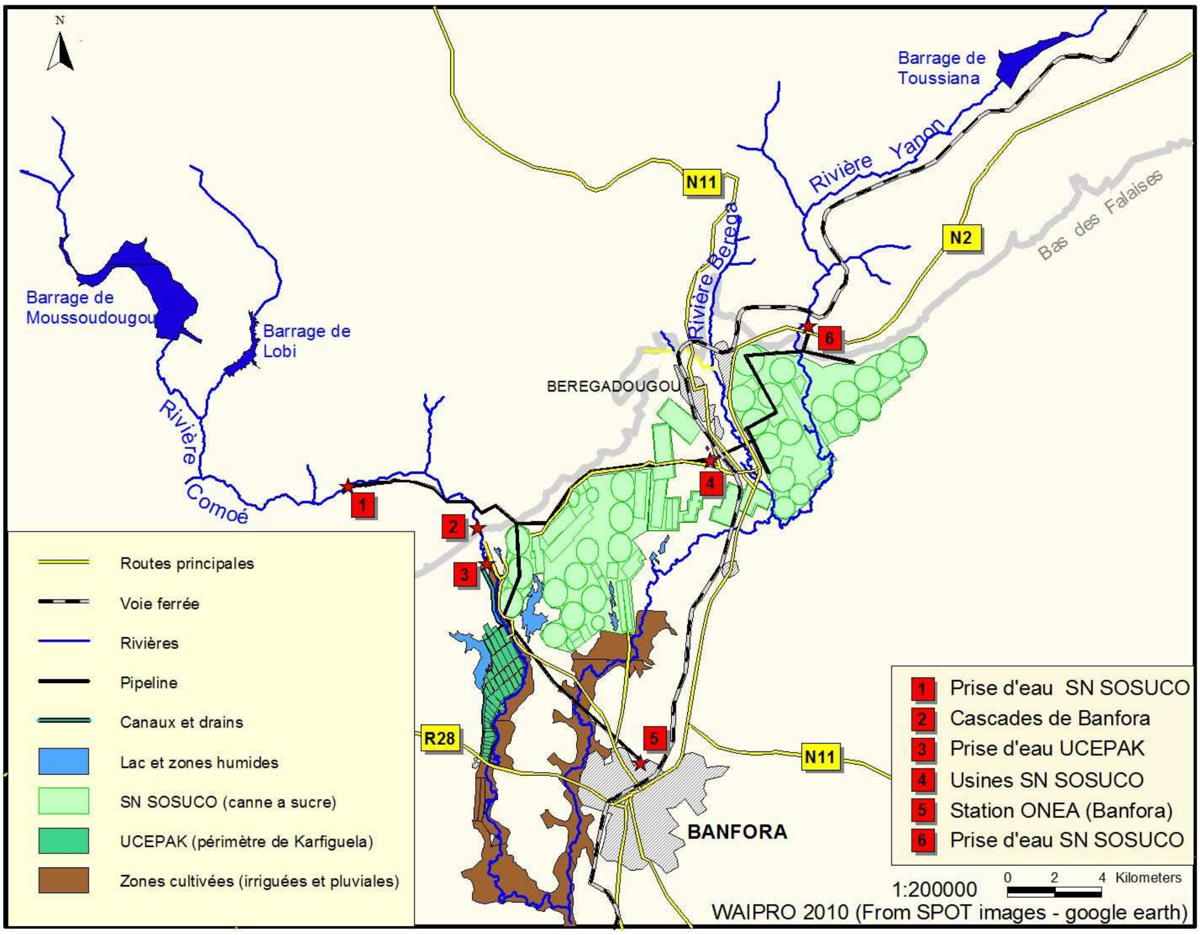
Figure 1: map showing the location of the study area in the Comoé River basin



(Source: WAIPRO)

The Comoé River is approximately 750 km long and it is an important source of agricultural water. A portion of the river in northern Ivory Cost runs through the Comoé National Park that was designated UNESCO World Heritage Site.

Figure 2: map of the study area



The study area has an area of approximatively 2000 km² (see figure 1 and 2) and comprises multi-sectoral water uses that have different but important impacts on the livelihoods of the local people and on the national economy as a whole. Various water uses co-exist in the basin, including domestic and livestock water supply, irrigation, fishing and touristic sites water supply. The study area comprises two major rivers, the Comoé river and its affluent, the Yanon river. The Comoé river and the Yanon river are regulated by three dams that provide water for irrigation, domestic water to Banfora and for downstream uses.

The rainfall is fairly high for Burkina Faso: it ranges from 900 mm to 1100 mm but is also characterized by intense seasonal and inter-annual variability. The wet season lasts from June to October. The dry season, with virtually no precipitation at all, lasts from October to April.

The rainfall and the good quality of the soil give one of the best agricultural potential in Burkina Faso The main crops are rain fed maize and yams, vegetables, rain fed rice, cotton, sugar cane and irrigated rice.

During some years there is not enough water for all these uses and restrictions are imposed. Since two years a Local Committee for Water (CLE) was established to enable a dialogue between various water users. The CLE implementation was part of a broad reform launched in the 1990's to improve the water sector. The legal and institutional frameworks were modified based on the concept of Integrated Water Resource Management (IWRM).

2.2 Water available and water uses

The three dams (Moussoudougou, Lobi and Toussiana dams) form a complex system that supplies water through pipelines to the sugar cane plantations (about 4000 ha) of the Société Nouvelle – Société Sucrière de la Comoé (SN SOSUCO) and to the local Office National de l'Eau et de l'Assainissement (ONEA) – the Water Utility that provids water to the City of Banfora (70 000 hab). The dams and the pipeline system are controlled by the SN-SOSUCO which must legally release an "environment flow" of 150 l/s, which serves mainly to maintain the Banfora Cascades waterfalls (an important tourist attraction) and the Karfiguela irrigation scheme (350 ha). Moreover between 400 and 900 ha of vegetables are grown (using about 200 pumps) on the banks of the Comoé and Yanon rivers.

There are a number of reports and papers that describe the different water users, thus Roncolli et al. (2009), Etkin (2008), DREDC (2005) provide a description of the different water users and of water resources management in the area. Etsher (1995), DPAHRHC (2009), CNID-B (2010), Diallo (2006) or Ballo (2010) provide a detailed description of the Karfiguela Irrigation scheme.

From the existing reports and studies reviewed, it appears that although there have been several attempts to quantify and model the "water system" (AEDE, 2009, Orstom 1997, Etkin 2008), there is still a lack of data especially concerning water uses and the Comoé and Yanon rivers flows. Several studies relied on estimates of water demands and water available that differ significantly. It concerns for instance the dams inflows, the dams capacities (especially the Lobi dam storage that varies from 2 to 6 Mm^3), the Karfiguela irrigation scheme net and gross water demands (varies from about 5 to 8 Mm^3 per season) or the informal irrigation area and water use. This lack of data was partially filled in by modelling work and the development of several models and decision support tools but there are still too many uncertainties affecting the precision of the modelling to precisely represent the system.

Table 2 was built using the main figures found in the literature. The figures in red are those that need to be considered cautiously. There are some uncertainties concerning, for instance, the water used by the Karfiguela irrigation scheme (8.4 Mm^3) that was obtained by estimating the maximum amount of water that the scheme could demand. In the table the water used by "pirates" (informal farmers located on the banks of the Comoé and Yanon rivers) is also an estimate as their water demand is not well known. The "environmental flow" (also called sanitary flow) needs to be taken carefully as it represents the 150 l/s released by the SN SOSUCO for downstream uses. In reality, this water is diverted almost entirely by the Karfiguela intake. The "unplanned flows" provided by Etkin (2008) takes into account the uncontrolled river flows that spill over the dams and flow downstream. It means that if the SN-SOSUCO does not release more than the required sanitary flow, the water used by the Karfiguela irrigation scheme cannot exceed 2,7 Mm^3 or 5, 3 Mm^3 (if the unplanned flows are added).

Table 2: Water balance based on estimates found in the various reports

Dams	Volumes (Mm^3)	Users	Volumes (Mm^3)
Moussodougou	31,3	SN SOSUCO	31,2
Lobi	1,0	Karfiguela	8,4
Toussiana	3,6	ONEA	0,5
Base flows	13,7	« Pirates »	9,5
		Env. flows Unplanned flows	2,7 2,6
Total	49,7	Total	55, 1

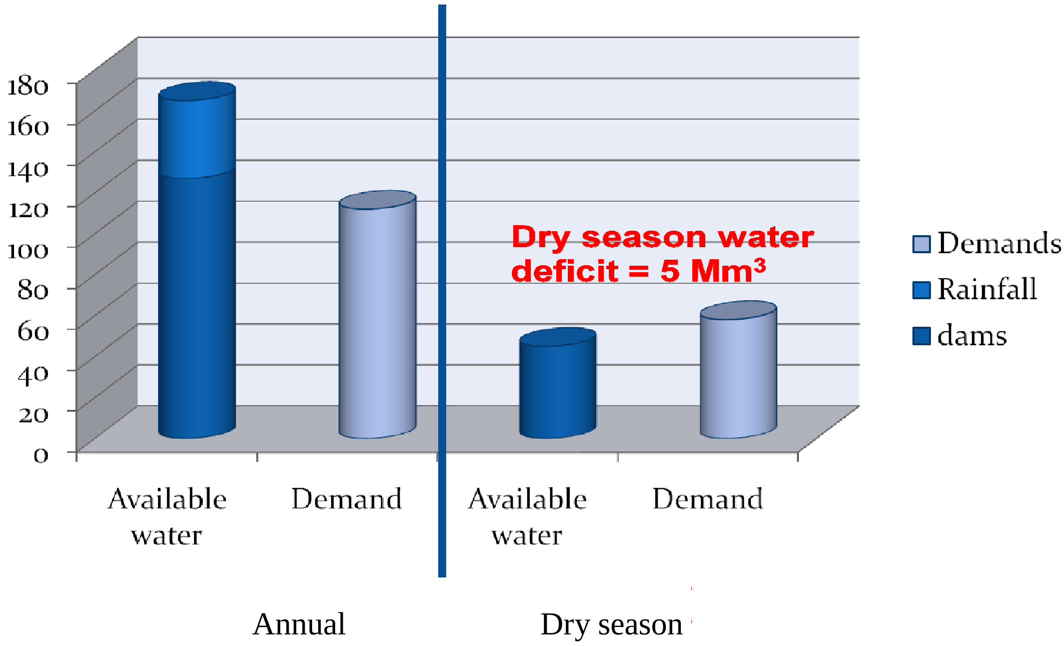
Figures in red: Important uncertainties concerning data, especially water demands for Karfiguela and pirates users and concerning the definition of the « environmental flows ».

The different studies all seem to agree that there is a water deficit in the area (ranges from 2 to 5 Mm^3 per year) and although there are uncertainties affecting the modelling, these results seems to confirm what is observed on the ground. In 2009/2010 there was indeed a water deficit of about 3 to 4 Mm^3 (to irrigate 350 ha of rice in Karfiguela) but the members of the

CLE committee and the SOSUCO irrigation officer claim that it was due to the low water levels in the dam at the end of the 2009 wet season.

Figure 3 shows estimates of the annual and dry season water available and water demands in the area based on the data provided by the AEDE (2009) study and Roncoli et al. (2009). The water available and the water demand were estimated for the 2008/2009 dry season and considered that Karfiguela irrigates 350 ha of rice during the dry season.

Figure 3: Graph showing the annual and dry season water balance

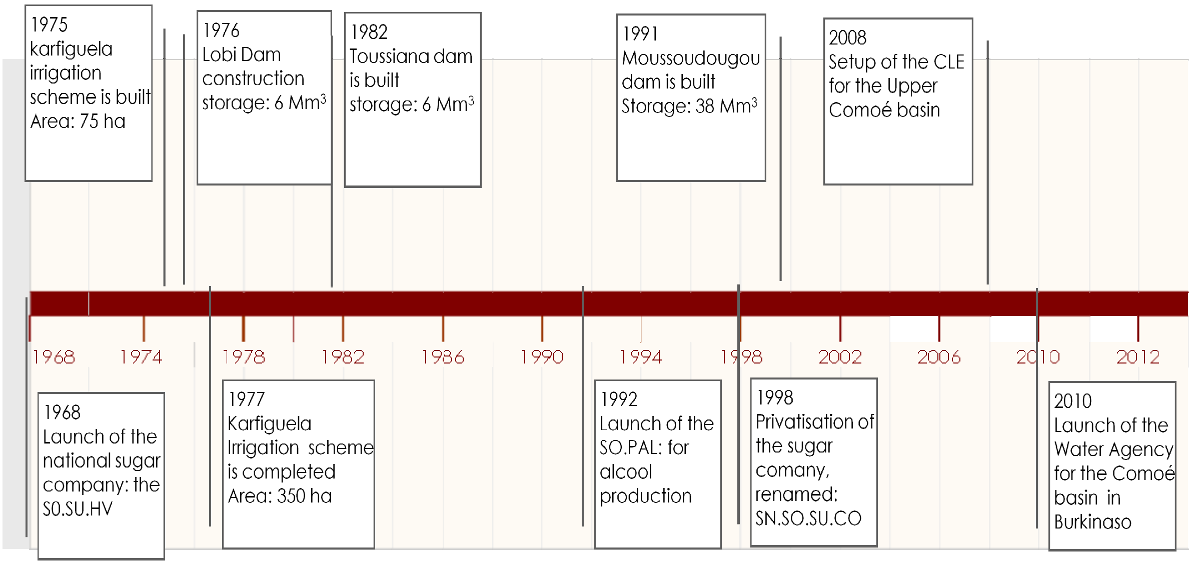


The graph shows that the water deficit is a dry season deficit. According to AEDE (2008) there is a 5 Mm^3 water deficit if all water demands are to be met.

This water deficit is, at the moment, compensated by “efforts” made by the SN SOSUCO (occasionally reducing its irrigation rate on some sugar cane fields to increase water released for downstream uses) and moreover the Karfiguela farmers who “accept” to reduce their dry season irrigation water demand (decrease irrigated areas). To understand, these efforts it is important to understand that historically speaking the Karfiguela irrigation scheme was created for supplementary irrigation during the wet season and it was built to relocate the villagers that were chased from the area were the SOSUCO fields were created. As a results, the SN SOSUCO are sort of bound to the Karfiguela farmers, and the latter know that they were not supposed to irrigate during the dry season.

To understand the situation, and especially the relations between water users it is important to have in mind the history of the area. Figure 2 presents a simplified timeline of the main events that occurred in the area.

Figure 4: timeline of the main water-related dates



The timeline shows that although the SOSUCO and the Karfiguela irrigation schemes were built in the beginning of the 1970's, the Lobi dam (6 Mm3), the Toussiana dam (6 Mm3) and the Moussoudougou dam (38 Mm3) were built in 1976, 1982 and 1991 respectively. It means that although the water available rose, the irrigated areas did not change. Both schemes (Karfiguela and SOCUCO) always had to cope with the water available to irrigate. This sort of equilibrium was "perturbed" when the dams, and especially the Moussodougou dam was built in 1991, the Karfiguela farmers then decided that the dam would allow them to do some double cropping. The dam also allowed the SOSUCO to build an energy free irrigation system solely depending on the Comoé and Yanon river intakes and abandoned pumping water from the various lakes in the area. The dams provided the SN SOSUCO with a year-through reliable source of water. The SN SOSUCO maintained supplementary irrigation during the wet season and full irrigation during the dry season .

The table 3 shows the area cultivated with sugar cane and the yields of sugar obtained from 1980 to 2005. Although the available water has grown with the construction of the 2 dams it only allowed the sugar yield to raise from approximatively 7,13 tons of sugar per hectare on average before 1991 (Moussodougou dam was built in 1991) to 8,55 tons par hectares. There was yield increase but it may not reflect the more significant increase of the water supply. This may have several origins, for instance the yield increase may have been more significant in terms of sugar cane produced than in sugar but that would mean that the transformation mechanisms (to sugar) became less efficient.

Table 3: SOSUCO areas cultivated with sugar cane and yields of sugar from 1980 to 2005

Years	Area (ha)	Sugar yields (tons/ha)
1980-1981	3749,8	6,8
1981-1982	3762	7,55
1982-1983	3719,9	7,45
1983-1984	3714,8	7,08
1984-1985	3773,9	7,25
1985-1986	3746,8	7,19
1986-1987	3615,4	7,31
1987-1988	3731,9	6,99
1988-1989	3589,8	6,11
1989-1990	3659,8	7,59
1990-1991	3448,3	7,19
1991-1992	3550,9	8,07
1992-1993	3570	7,88
1993-1994	3603	8,64
1994-1995	3559,9	8,14
1995-1996	3510	8,06
1996-1997	3584,6	8,9
1997-1998	3639,8	7,99
1998-1999	3498,2	7,08
1999-2000	3597	8,76
2000-2001	3625,6	9,76
2001-2002	3681,1	10,01
2002-2003	3671,93	10,02
2003-2004	3754,7	8,59
2004-2005	3671,51	7,83

(Source: SN SOSUCO, 2005)

It would be interesting to analyse the evolution of the water balance throughout the years from 1975 to 2010 as it could help to better understand the impact of the dams and the evolution of the water demands but the data required for such analysis are not available. These analyses could, for instance, bring some new elements of understanding on issues such as the relationship between the Karfiguela farmers and the SN SOSUCO.

3. Existing water management tools and their potential use

3.1 Existing tools

The literature shows that several models for the management of water resources were developed in the study area. The existing models that were identified from the literature are as follow:

- ORSTOM (1997) modeled the area using the HYDRAM model- HYDRAM is an unix based generic model.
- Modeling done by the AEDE (2009), there were no proper tool developed, the water resources and demands were estimated.
- Development of two different DST by the project called "Improved Water Resources Management in the Sahel-Sudan, a Case Study of Burkina Faso" (2009). University of Georgia and Tuft University (US). The two DST are the:

    1. **Multi-stage stochastic linear program** (MSSLP)
    2. **Comoé simulation tool (CST)** presented to the CLE

Because HYDRAM runs under *unix* (cannot be used easily by users having windows OS) and since the MSSLP is a very complex tool, these two tools were not considered as having a high potential of use by water managers in the current situation. The only existing tool that was actually run and evaluated is the Comoé simulation tool (CST). Nevertheless, the MSSLP was described and its potential uses assessed on the basis of the documentation provided by its developers. The CST and MSSLP are described and evaluated in the following sections.

The MSSLP is a stochastic prescriptive optimization tool that was developed to optimize the management of the three dams and the water uses of the study area. The CST was developed to answer the requests made by members of the CLE. It is a more simple deterministic simulation model than the MSSLP. The CST was therefore developed as a first step to prompt the collection of water uses and demand data and ease communication between water users within the CLE. The developers envisaged that the MSSLP would be handed over and used by the CLE once they are comfortable with the CST.

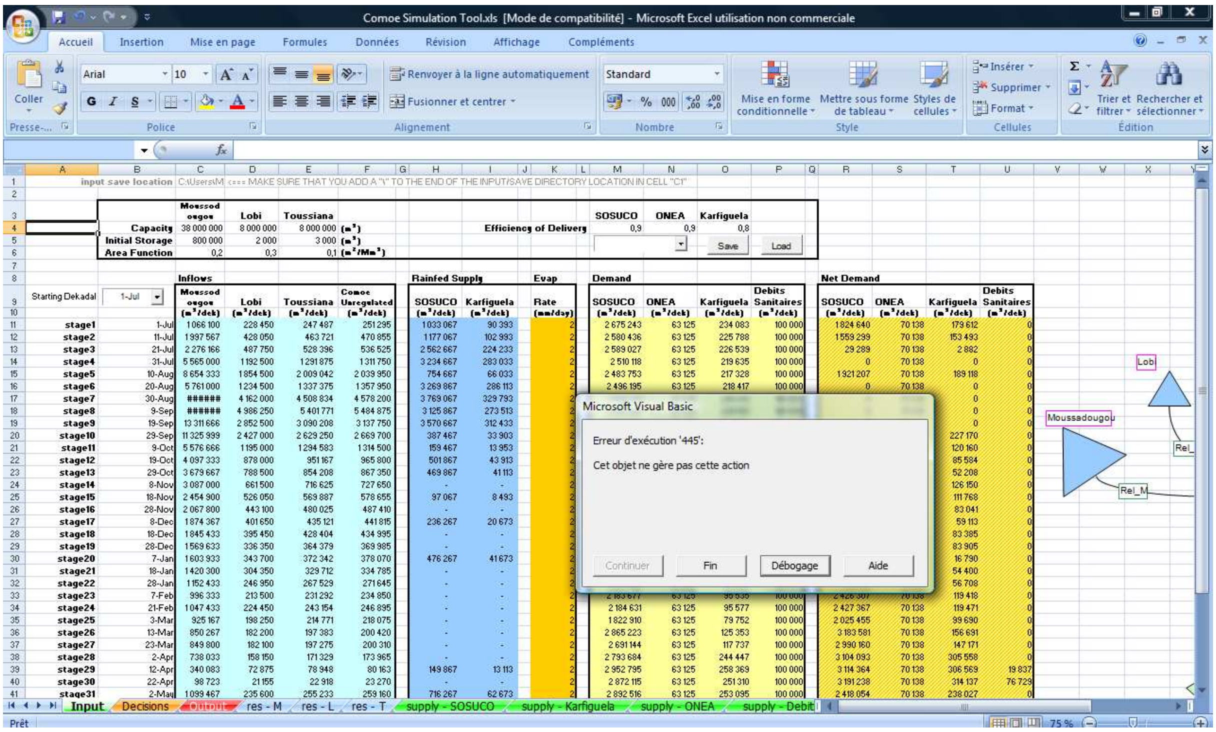
Thus, Etkin (2008:29) states that:

> *"The deterministic simulation model … is only a first step in a process to use information technology to improve the integrated water resources management of the Comoé River Basin. While the simulation model provides water managers and users with an improved and shared knowledge of the system dynamics, it cannot explicitly describe the uncertainty of future streamflow and precipitation. Additionally, it functions only in a descriptive capacity and cannot prescribe optimal operational decisions in its present formulation.*
> *The goal of the multistage stochastic linear optimization model is to consider multiple uncertain futures and optimize current operations to meet current and future needs. The formulation allows the program to be run by operators at any point during annual operations with a one year forecast horizon."*

3.2 The « Comoé Simulation Tool »

The Comoé Simulation Tool (CST) was developed by the "Improved Water Resources Management in the Sahel-Sudan, a Case Study of Burkina Faso" project conducted jointly by the Tuft and Georgia Universities. The tool development was described by the project as the first step in a larger project aiming at providing information tools to facilitate integrated water resources management.

Figure 5:



Etkin (2008a) states that the CST “assists Comoe River managers with organizing, processing, and discussing the Comoé River basin system inputs and demands, and allows different operational decisions to be evaluated with respect to the incurred deficits.”

The CST is a water balance model, considering the three dams (Moussoudougou, Lobi and Toussiana dams) and the Comoé river until downstream of the UCEPAK irrigation scheme intake.

The CST was developed using Visual Basic for Applications (VBA) to construct a graphic user interface based on a Microsoft Excel workbook. The use of VBA is an advantage as it is a standard package available with all available versions of Excel and not computationally demanding. Thus, Etkin (2008a) explains that “the broad familiarity of Excel outside academia and engineering makes it accessible to a wider set of possible users involved in the integrated water resources.”

The CST models a period of one year using a decadal time step, for each decade it models the water balance using the forecasted hydrologic inputs and water demands. The user can use the CST operational algorithm or manually input release and diversion schedules to allocate water resources to the demands. The hydrological year used in the CST starts on the 1st of July which does not correspond to the start of the rainy season-this issue should be discussed with potential users in order to know if it is a logical choice from the managers’ point of view.
For each time step, a set of releases and diversions need to be set (either manually or using the built-in model), these are called “decisions” in the CST. There are 6 decisions that need to be set:

(1), (2) and (3): reservoir releases from each of the three reservoirs,

(4) : diversions from the Comoé pipeline to the SOSUCO irrigation scheme,

(5): diversions to the ONEA Banfora distribution system from the Comoé pipeline,

(6): the diversion at the Karfiguela Plains water intake from the Comoé.

There are three nodes remaining in the network that can be calculated from these 6 decisions:

(7): total pipeline diversion from the Comoé,

(8): flow in the Comoé downstream of the pipeline diversion and upstream of the Karfiguela Plains intake,

(9) the Comoé flow downstream of the Karfiguela Plains (or “débits sanitaires”).

The first tests run using the CST and the fact that it is excel based, showed that it has a high potential, its main advantage being its “simplicity”. There are, anyway a number of issues that need to be solved before it can actually be used by water managers.

The main improvements required are as follow:

1. Debugging: There are a number of programming” bugs that prevent its normal use. Because the CST is developed using VBA, these programming errors should be rather easy to solve.

2. Translation: the tool itself, the user manual and the other documentations are in English which will hamper its potential use in Burkina Faso. The CST and related documentations must be translated in French.

3. The user manual and especially the tutorials are very limited and need to be improved and completed. Exercises that fit the reality of the situation in the area should be built in order for the user to learn how to use the various components of the tool. These exercises should be developed in a sequence that increases the complexity of the tasks to be done by the user.

4. There are different modelling issues that could require some more modelling and programming work:
    1. Informal users (riparian farmers on the Comoé banks) are not modelled as a water demand, they are considered as benefiting from the « sanitary flow ». Considering that informal irrigation seems to increase in the area (they are supported by a series of projects, subsidies etc) they must be included as a water demand.
    2. There is no connection between the east pipeline (from Toussiana) and the west pipeline, this connection allows the SOCUCO to supply ONEA or the western part of the sugar cane fields when needed (e.g. the Moussoudougou dam is empty).
    3. The return flows from the Karfiguela and SOCUCO fields are not modelled. The later seem to have a strong influence on the flow in the Comoé river downstream of the UCEPAK intake. Indeed, the

drainage water of the SOSUCO fill the Lemeroudougou lake which itself feeds the Comoé through a canal.

4. The Lobi dam was modelled using its initial storage, but it is so considered as fragile and its real capacity decreased from 6 Mm^3 to 2 Mm^3 approximatively. This assumption will tend to increase significantly the available water in the plain.
5. The sanitary flow as it is modelled does not fit the reality. The sanitary flow is in reality released by the SOSUCO but most of it get taken by the UCEPAK intake. The sanitary flows were modelled as a "how it should be" scenario instead of "what it is".
6. The type of results produced and their display (as graphs) will require some improvements, or at least to be reviewed by managers and some water users in order to ensure that they fit their needs and allow better decision making.

The CST seems therefore to have a high potential but requires some improvements in order to be ready to use by local water managers. Another key issue that was raised by several members of the CLE committee and staffs of the provincial and regional directions is the uptake of the tool. Although several members of these "institutions" attended the two workshops where the CST was presented, they complained that no institution was clearly identified to host and use the tool.

3.3 Uptake of the CST by the CLE committee ("comité restreint")

The choice of the host organisation is critical in order for the tool to be accepted and used, and for its results to have an impact on the decisions taken by the CLE. There are a number of organisations that are involved in the management of water in the study area. The host organisation will have to run the tool, update its data and produce results that will feed in the discussions and negotiations taking place within the CLE and especially those taking place during the committee meetings.

On the basis of discussions held with the Chief of plain ("chef de plaine"), the host organisation will have to regroup the following characteristics:

1. Neutrality in front of all water users
2. Legitimacy to actually contribute to the negotiations

3. Human resources with skills in hydrology, modelling, data analysis etc.
4. Human resources with skills in IT.
5. Authorised to be part of the committee meetings

On the basis of the discussion held with the chief of plain, several organisations involved in water management were evaluated according to the characteristics listed above in order to assess their capacity to host the CST. The notes were given as an exercise and should not be reused or quoted. The list of organisations that were evaluated is not exhaustive and the identification of the host organisation will require true participation of the different local stakeholders. Table 4 shows the result of this evaluation.

Table 4: Evaluation of the capacity of some institution to host the CST

Institution	**neutraliy**	**Legitimacy**	**HR in hydrology**	**RH in IT**	**Part of the CLE committee**	**TOTAL**
Dir. Provinciale		+	+	?	+	**++++**
Conseil Regional	+	+		?	+	+++
Dir. Regionale	+	+		?		++
SN SOSUCO			+	+	+	+++
UCEPAK					+	+
AEDE	?	?	+	?	+	+++
INERA	+	+		+		+++

On the basis of this rather rough and partial evaluation, the provincial service of Agriculture (Direction provincial) appears as a proper host organisation.

This evaluation has shown that the CST could meet its objectives of assisting the CLE to take decisions regarding water sharing towards IWRM if it is improved and if the issue of its uptake is considered seriously. It is important to note that the Millenium Challenge Account programmes[1] are considering the improvement and use of the CST in the Upper Comoé basin and to adapt it to other sub-basins of the Comoé river basin. The CST has a high potential but the improvements that are required may limit its implementation. Nonetheless, the data that were collected and the modelling work that was achieved (particularly, the forecasting data

[1] Personal communication of the Director of the MCA office in Ouagadougou that was involved in the development of the CST.

generated) should be reused as they contribute to improve the understanding of the study area and could be used for testing and setting up other tools.

Beyond the decision of actually improving the CST, there are number of questions that need be answered. Firstly, whether there is a need for decision support tools in the area? Secondly, has any local organisation the capacity to use and moreover to maintain the CST? Lastly, are there any generic tools (e.g. WEAP) that could be ready to use more easily? The first question is partly answered in section 4 of this report, whereas the second and third questions would require more work to be answered.

3.4 Multi-stage stochastic linear program

The MSSLP "translates conditionally weighted scenario-tree of streamflow and precipitation forecasts into optimal release schedules for reservoir operators to implement in real-time as forecasts and system conditions change" (Etkin, 2008). The MSSLP was developed to be run by reservoir operators every decadal, with updated input data as hydrologic and operational events are realized. The operators could then foresee the decision variables throughout the year-long forecast horizon and evaluate their own decisions for the current decadal. The MSSLP and the CST share a number of characteristics:

- Same system description (dams, pipelines, nodes, water users etc.),
- a one year model horizon of 36 decadal time steps,
- The reservoir releases and network diversions comprise the set of decision variables,
- The constraint that define the dynamics of the reservoirs and conveyance network.
- The DST is constructed of several interlinked worksheets in a single Microsoft Excel workbook.

Although there are some similarities between the two DST, the MSSLP differs from the CST as the set of decision variables are optimized by an objective function that determines the set of dam releases in the present that minimizes deficits both in the present time step and in the future as well as the final amount of reservoir storage. The parameters describing future reservoir inflows and precipitation inputs are expressed probabilistically using a scenario tree. The MSSLP is an excel based tool, while Excel "handles" the large sets of input parameters and output decisions, the data processing is programmed in VBA while the MSSLP itself is coded and solved using the GAMS which is interfaced with the Excel workbook. The structure and components of the MSSLP are presented in the next section.

1.1.1. Structure and interfaces of the MSSLP tool:

The following paragraph summarise the different components of the MSSLP tool paraphrased from Etkin (2008).

The DST is constructed of several interlinked worksheets in a single Microsoft Excel workbook. Each worksheet performs a different task in the process. The first several worksheets are used to process historic daily precipitation data to be built into a five-stage decadal time step branching scenario tree. Each historic year is divided into six stages (five plus a dry season), and calculates the first two moments of each historic stage. With the moments calculated from the historic record, analogue years are selected for the tercile (high/med/low) of each stage.

On another worksheet the probabilities of each branch of the precipitation scenario tree are calculated from the historic record using algorithms programmed in VBA. Markov transition matrices are determined from counting the transitions between tercile states (high/med/low) between stages in the historic record. Using VBA these Markov matrices are expanded into a branching tree construction of conditional probabilities, and then into a single probability matrix for each state and stage. The probability matrix can be adjusted by seasonal tercile forecasts developed in collaboration with ACMAD

After the analogue sequences of decadal precipitation are selected for each stage and tercile, another worksheet constructs a five-stage branching scenario tree of decadal precipitation for one year. This precipitation scenario tree is a stochastic description of climatology, based on the available historic record.

On the following worksheet the precipitation scenario tree is used to construct a streamflow scenario tree for the Diarabakoko stream gauge with an ABCD rainfall runoff model that is coded in VBA. Reservoir inflows for each scenario are estimated by area ratio from the streamflow at Diarabakoko.

Another worksheet calculates the effective precipitation supply for SOSUCO and Karfiguela agricultural demands from the precipitation scenario tree and the inflow scenarios for each reservoir by area ratio from the branching scenario tree for Diarabakoko.

On the main worksheet the user can enter reservoir network parameters (max storage, max release, storage-surface area function, conveyance efficiency), total decadal demands for each water user, and the parameters of the time-variant multi-objective piecewise linear penalty function. A VBA algorithm translates the data on this and other worksheets into a multi-stage linear program in GAMS code, and then calls on GAMS to solve the linear program.

After the linear program is solved in GAMS, the output is read back into the worksheet. The output includes the optimal set of release and diversion decisions.

Figure 6: screen capture of the MSSLP

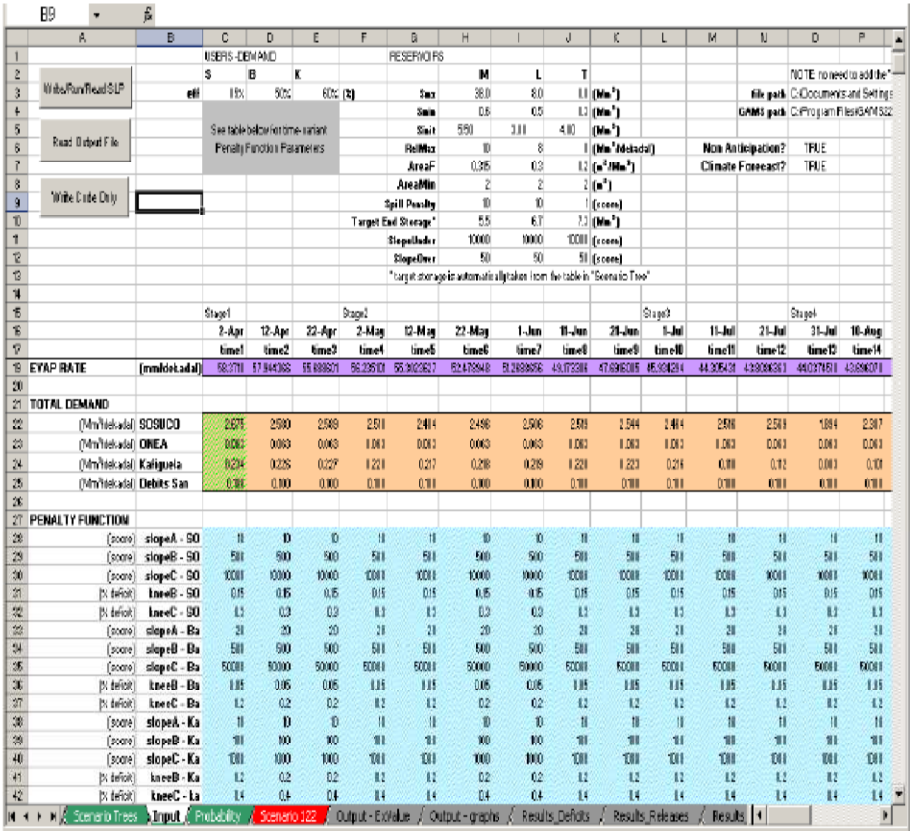
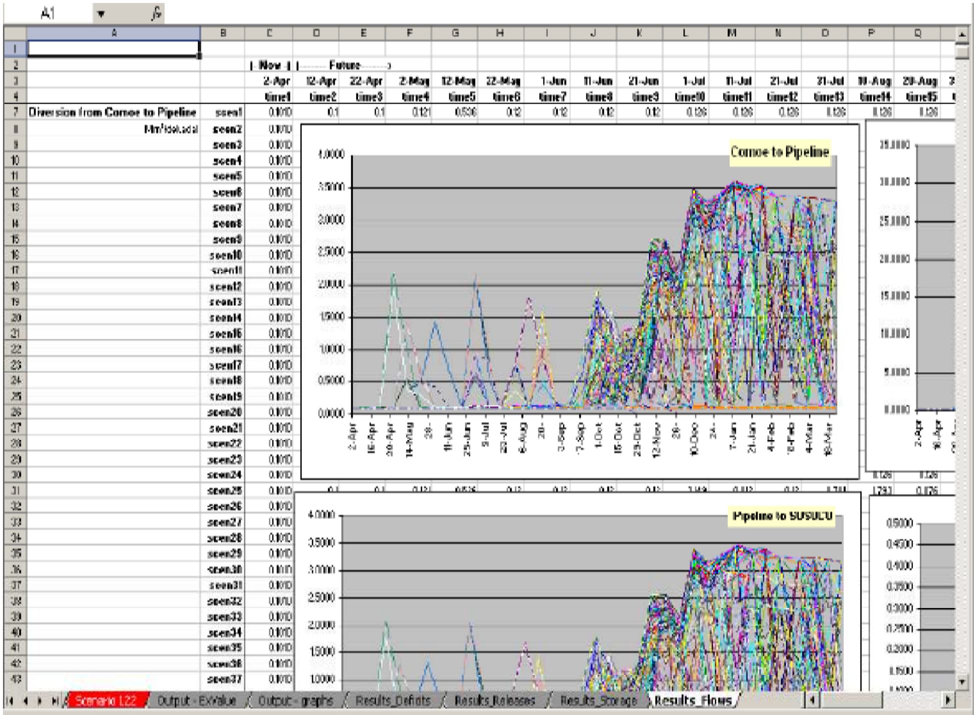


Figure 7: screen capture of the MSSLP



The MSSLP was tested and evaluated by the developers themselves but could not be tested by the users. The lack of data was as well an obstacle for the evaluation of the tool as “simulated” decisions concerning the dams could not be compared to historical dam operations data. Etkin (2008) attempted to test the decisions recommended by the tool under historic conditions (2003 to 2006) using different set of data (perfect information, climatologic forecast, historic ACMAD forecast, improved retrospective tercile forecast). Etkin (2008:114) concluded that the range of deficits experienced by each demand is identical for each simulation mode but that:

> *“…there is a slight overall reduction in the volumetric deficit experienced by the ONEA and Karfiguela demands as a result of the application of the ACMAD forecast, and a slight increase in the deficits experienced by SOSUCO. The total deficits incurred with an application of ACMAD forecasts actually exceeded those of an application of simple climatologically based forecasts. This may say more about the quality of the ACMAD forecast than anything else. The “Improved” Retrospective Tercile Forecast slightly improves the supply of water to all three users as well as reducing the overall volumetric deficit for the period. Not surprisingly the largest overall improvement arises from the application of perfect information.”*

The MSSLP DST for the Comoé Dams management could not be tested before writing this report, but based on the documents provided by the developers the following conclusions can be drawn:

- The modelling work achieved, and especially the reconstructed dams inflows data as well as the forecast methods tested are important contribution towards more informed management of the dams.
- The tool still requires improvements on the modelling side as noted by the developer himself (Etkin 2008).
- The tool needs to be translated in French
- The graphical user interface needs to be rendered as easy to use as possible

The MSSLP was developed to be run by dams managers every decadal to simulate and plan the reservoir operations for the next decadal. It is maybe more realistic to envisage that the main use of this tool could be to assist the CLE at the end of the wet season to decide the water that will be allocated to each user and especially the water that will be released for the Karfiguela irrigation scheme during the dry season. It means that the water allocation decisions will have to be taken based on the water level in the dams (as it was done by the restricted committee in 2009) and will require precise weather forecast of the dry season and especially of the beginning of the next wet season (necessary to run the MSSLP). This would improve greatly the potential of the DST but further tests will have to be realised in order to ensure that the ACMAD weather forecasts or the climatologic forecast are precise and reliable enough.

The MSSLP is a rather complex tool both from a modelling and handling point of view, and although it produces interesting results its complexity and the modelling work still required to improve it will seriously limit its potential use by members of the CLE. Nevertheless, as it was noted by Etkin (2008) it could be envisaged to introduce the MSSLP only after the members of the CLE are comfortable with the use of the CST.

3.5 Available Data

A review of the data produced by the national institutions shows that the main data producers are the DGRE (Direction Générale des Ressources en Eau), the DGPSA (Direction Générale des Prévisions et de la Statistique Agricoles), the ONEA (Office National de l'Eau et de l'Assainissement) and the DMN (Direction de la Météorologie Nationale).

Table 6 : data produced by the national institutions

Institutions	Data produced	remarks
DGRE	Surface water data (stored in the HYDROM database) Water sources (assessment done in 2005) Some data on small dams and irrigated perimeters	-The data is supposed to be accessible from the web or from their database. -The DGRE is also supposed to collect and provide data on dam storage level. But the data found on the three dams is collected by the SN SOSUCO itself -DGRE maintains two river gauges in the area but **Diarabakoko station** is the only station with records preceding the construction and operation of the reservoir network.
DGPSA	Crop production statistics Surface water uses (mainly cereals and vegetables) Farmers organisations, number of farmers, types of water sources number of farmers per water sources Cultivated areas, production and productivity (estimated) Rainfall and production deficits	These data are produced at national level on a yearly basis, but the data concerning the study area could not be retrieved for this report but they should be available at the Regional or provincial level.
ONEA	The main data produced concerns the quantity and quality data of the water supplied. The ONEA also collects socio economic data concerning the users through surveys.	These data are produced in annual reports and are available at the ONEA Banfora office.
DMN	They collect rainfall and agro-climatic data through their station network. The data are collected and stored in the Clidata database in Ouagadougou.	The rainfall stations located within or near the study area are: Moussodougou, Lobi, Toussiana, Nianka, Beregadougou, Banfora, Banfora (agro-meteo), Sindou, Sideradougou and Soubaka stations. The data collected from these stations are available at the DRAHRH. Only few stations have full (or almost full) historical data. The Banfora station has reliable data from 1963 up to now.
BDOT	Land use and hydrography	GIS data of land use and river network
DRED	Socio-economic data at the village, department and provincial level	Data was published in the report “Monographie de la province de Comoé’.

Apart from the data produced by national institutions, data can be obtained from users themselves such as the SN SOSUCO and the UCEPAK (number of members, area per member etc). The SN SOSUCO collects daily agro-climatic data and water volumes diverted from the Comoé and Yanon rivers intakes. The SN SOSUCO also collects a number of data such as their yearly production of sugar cane, sugar, alcohol and intermediate products production and their yields. They also record the dams' levels but this activity must have started recently because there are no historical dam storage data available.

Another important source of information and data are the numerous projects and study reports produced over the years in the Comoé river Basin. The data and information collected and produced by these projects is an important source of information. The data produced by these studies are as follow:

- IWACO-ORSTOM project collected information concerning the irrigation schemes in Burkina Faso (i.e the Karfiguela irrigation scheme),
- AEDE produced estimations of the water available and water demands for the different water users and the amount of water stored in the 3 small lakes of the study area
- ORSTOM produced the simulated the dam storage and hydrological flows using historical rainfall data and estimated water demands
- The data that was collected and moreover the modelling work achieved for the development of the CST and the MSSLP is a very important source of data. The reconstruction of the historical dam inflows and storage level is one of the important data produced by this project.

3.6 Missing data

There are a number of data that are missing in the study area. The data listed in this section are those that were identified as needed for a better management of natural resources in the area and especially those that would help the CLE to better allocate water between users. Apart from the gaps in the rainfall/climatic/gauges stations data, the missing data that were identified are:

- Net demand of sugar cane fields to compare water diverted from the rivers to the actual water "used" by the sugar cane plants. This data would be very useful to check the high water productivity that the SN SOSUCO claim to have. Indeed, an analysis of the historical production data of the SOSUCO shows that the areas cultivated by the

SOSUCO have not increased significantly since the construction of the dams and their average yields only increased from about 7,1 to about 8,5 tons of sugar per hectares. The yield increase may not be sufficient to justify the use of most of the dams' water by the SN SOSUCO.

- Water stored in the three lakes with a special attention given to the Lemeroudougou lake and the volume of water that returns to the Comoé river.
- Volumes of water released at the SOSUCO intakes for downstream uses
- Volumes of water diverted by the Karfiguela intake
- Area cultivated by "informal" farmers, types of crops, number of motopumps etc.
- Net and gross water demands of the Karfiguela irrigation scheme.

At the Karfiguela irrigation scheme level there are a number of data that would be needed to better manage and better assess the productivity of the scheme. This includes hydrological, agronomic and socio-economic data.

The lack of data concerning the Karfiguela irrigation scheme may limit its capacity to negotiate water rights and the general lack of data may as well hamper the ability of the CLE to take rational decisions concerning water allocation.

4. Negotiating improved water rights for the Karfiguela irrigation scheme

The CNID-B (2009) conducted a rapid diagnosis of the Karfiguela Irrigation scheme and identified a number of rehabilitation works to be realised in order to improve the hydraulic functioning of the scheme. CNID-B (2009) and Diallo (2006) show that one of the main problem faced by farmers is the insufficient amount of water they receive for irrigation. The reports show that the lack of water is partly due to the state of the scheme itself (e.g. mismanagement, infrastructure deteriorated) and to the fact that – according to farmers – the SN SOSUCO does not release enough water. Following the Moussoudougou dam construction in 1991, the SN SOSUCO was releasing 300 l/s for downstream uses during the dry season, it allowed the irrigation of 350 ha of rice but later this amount was reduced to the minimum authorised: a sanitary flow of 150 l/s. The Karfiguela farmers coped with this decrease by reducing the area cultivated during the dry season, thus only two or three (alternatively) of the five cooperatives are allowed to irrigate their land every dry season. It seems that the SN SOSUCO is reluctant to actually release more water to the Karfiguela irrigation scheme because they consider that a big part of this water is actually lost before reaching the rice fields (Diallo 2006 and SN SOSUCO irrigation officer personal communication) or not properly used by Karfiguela farmers. The CNID-B and Diallo (2006) confirm that there are important losses in the system. The rehabilitation work that will be conducted by WAIPRO should reduce these losses at least partially but some efforts will have to be made on the management and maintenance of the scheme in order to ensure that the rehabilitation works achieve their goal.

Discussions held with cooperative managers showed that part of the problems linked to the maintenance of the canals and the drains and the reluctance of farmers to pay their fees comes from the farmers' frustration. The frustration rose year after years as the farmers prepared their land but could not get the water (quantity and timing) they expected.

In 2009, some negotiations were held at the end of the wet season during the restricted committee meetings. On the basis of the rather low water level in the dams, the SN SOSUCO stated that the Karfiguela scheme would get the water to irrigate 150 hectares during the dry season. These 150 ha would have to be irrigated using the 150 l/s released by the SN SOSUCO but farmers complained that they did not get sufficient water to irrigate the 150 hectares of rice. As a result some farmers had to abandon part of the fields they had prepared or shifted from rice to less consuming crops such as maize. As there are no gauging stations upstream of the Karfiguela intake or in the canals it is impossible to know exactly how much water was released by the SN SOSUCO and how much was actually received, lost and used by the Karfiguela irrigation scheme.

During the 2009/2010 dry season the Karfiguela irrigation scheme managed to get the SOSUCO to release more water occasionally by asking the Chief of valley from the DPAHRH to negotiate with the SN SOSUCO. These negotiations are usually done by phone between the chief of plain and the SOSUCO irrigation officer and do not go through the CLE. Some negotiations were done as well between the President of the Cascades region (also president of the CLE) and the SN SOSUCO. These negotiations between the chief of valley (he is not part of the CLE committee) are not done through the CLE and have no legal weight. Even discussion and negotiation held during the CLE meetings have no legal status as the CLE is a discussion and dialogue platform and has no legal power to ensure that the decisions taken are implemented. Apparently, the SN SOSUCO usually complies with these requests and releases more water during 2 or 3 days before decreasing again to the minimum required.

Based on the diagnosis realised and the discussions held with farmers and local managers it is clear that the irrigation scheme needs to be certain of getting a fixed amount of water and in the required timing. This can only be achieved by reinforcing the capacity of the Karfiguela Irrigation scheme to negotiate a sort of "water right" with the SN SOSUCO during the CLE meetings. Currently, there are no legal water rights in Burkina Faso, according to Diallo (2006) the only existing legal contract was signed between the SN SOSUCO and the state. The government actually transferred the management of the Moussoudougou and Toussiana dams to the SN SOSUCO. The Lobi dam was funded and built by the SN SOSUCO itself. This contract, their social and economic weight at the local and national level, the fact that they control the dam releases and the supply water to the Banfora City put the SN SOSUCO in a very strong position during negotiation.

There are a number of factors that affect the capacity of the Karfiguela irrigation scheme to negotiate water rights; these factors either have a positive or a negative impact. The positive and negative factors are described in table 7.

Table 7: Positive and negative factors affecting the negotiation possibilities at Karfiguela Irrigation scheme level

Positive factors for negotiation	Negative factors
□ Existing and working CLE □ Stakeholders used and ready to discuss and negotiate □ An "historical legitimacy" that gives the Karfiguela farmers the right to get clear allocation of water □ Political will for change and supporting the development of dry season irrigation □ A strong Regional and provincial department □ Several supportive projects in the area (WAIPRO, MCA, DADI etc.) □ Existing Decision Aid tools	✖ Water deficit in the area ✖ Not enough water reaching the rice fields ✖ Political, social (jobs) and economic weight of the SN SOSUCO ✖ Bad knowledge of water uses/needs in the Karfiguela irrigation scheme ✖ «Low» productivity of water in Karfiguela ✖ "Trust deficit" between SOSUCO and Karfiguela ✖ Currently, water rights do not exist as such in Burkina Faso ✖ No control mechanism of the CLE decision implementation ✖ DST not used

There are a number of favourable conditions that should allow the Karfiguela Irrigation scheme to negotiate for the water it needs. Thus, the CLE is one of the most active and "successful" CLE in Burkina Faso. The existence of the CLE, the fact that the scheme was built to provide an alternative to the farmers chased from the SOSUCO fields and the political support of the provincial and regional departments of agriculture are arguments that the farmers can use during negotiations. On the contrary, the economic weight of the SOSUCO, its strong position as manager of the three dams, the water deficit experienced in the area, the apparent low water productivity and the lack of data concerning the water needs and uses of the Karfiguela scheme are factors that limit their possibilities to negotiate for water.

Several ways can be envisaged to reinforce the Karfiguela irrigation scheme negotiation possibilities. A way of solving the issue is to solve the water deficit that often affects the area, thus the SN SOSUCO will be less reluctant to release more water or the Karfiguela irrigation scheme will get its water from other sources. Another solution consists of improving the productivity of water: release water by saving water. The fact that the Karfiguela irrigation scheme managers are unable to actually present their water demand, their water uses and productivity during negotiation is a very limiting factor during negotiation because these are the arguments put forward by the SN SOSUCO to limit the water releases. During negotiations, the SN SOSUCO uses scientific and management arguments to justify its use of water while the Karfiguela irrigation scheme managers use political and social arguments to justify their right for water.

The following sections presents the different solutions that can envisaged for improving the capacity of the Karfiguela irrigation scheme to negotiate better for the water it needs.

4.1 Reinforcing the negotiation possibilities of the Karfiguela irrigation scheme

The fact that historically the SOSUCO has to compensate the Karfiguela farmers and the political willingness at the regional and national level to boost food production gives the Karfiguela farmers a sort of "political argument" to claim for more water. On the contrary, the SOSUCO uses scientific and rational arguments to claim for water. Apart from the fact that they actually control and manage the dams and the releases, the SOSUCO claims that the dam intakes, the pipeline and the modern irrigation methods they use allow them to use water very efficiently and they are therefore reluctant to sacrifice water to supply the “inefficient Karfiguela irrigation scheme” (SN SOSUCO irrigation officer personal communication).

To provide the Karfiguela irrigation scheme the scientific arguments required to negotiate with the SN SOSUCO there are a number of measures that need to be taken. The rehabilitation work planned by WAIPRO should help the Karfiguela irrigation scheme to improve its water productivity. WAIPRO should as well provide monitoring tools that will help the UCEPAK understand its needs in terms of water, monitor and evaluate its own productivity.

The actions planned by WAIPRO to reinforce the agricultural production at the plot level and the management organisation may take longer than rehabilitating the irrigation system. There is a risk that the rehabilitation of the irrigation system per se will not be sufficient on its own to increase the productivity (at least at the beginning), farmers and their cooperatives could therefore be reluctant to monitor their productivity if it is low. It is therefore important to put in place a long term monitoring system that will show the productivity increase over the years. In that case, even if the water productivity does not reach the level of the SN SOSUCO, Karfiguela farmers will be able to use the water productivity increase as a scientific argument to ask and negotiate for more water. To ensure that the monitoring system is used on the long term, the farmers and the cooperatives must understand that it is in their interest to maintain it. Putting in place a monitoring system implies that they have the financial, human and technical resources to do so. The provincial department of agriculture could assist the cooperative by providing their support (as they already do).

From the literature and moreover from discussions held with CLE members it seems clear that the Departement of agriculture, the provincial direction of agriculture and the president of the region des Cascades (also president of the CLE) will push the SN SOSUCO to release more water to supply the Karfiguela Irrigation scheme and for other downstream uses including the sanitary flows. The willingness to develop food production also concerns small informal farmers, they are being supported by NGOs and governmental projects (e.g the PADL programme that subsidises moto-pumps up to 35% for instance). If the double cropping in the Karfiguela irrigation scheme is considered as a right and if the informal farmers are not considered as pirates but “almost formal” farmers then it become certain that some efforts will be needed to either decrease the water demand and/or increase the supply.

4.2 Ensuring the water supply

There are two types of measures that can be taken for the demand to be met by the supply; some of these measures are demand driven whereas others are supply driven.

4.2.1 Supply management solutions

The three solutions envisaged here to increase the supply of water in the area are the following:

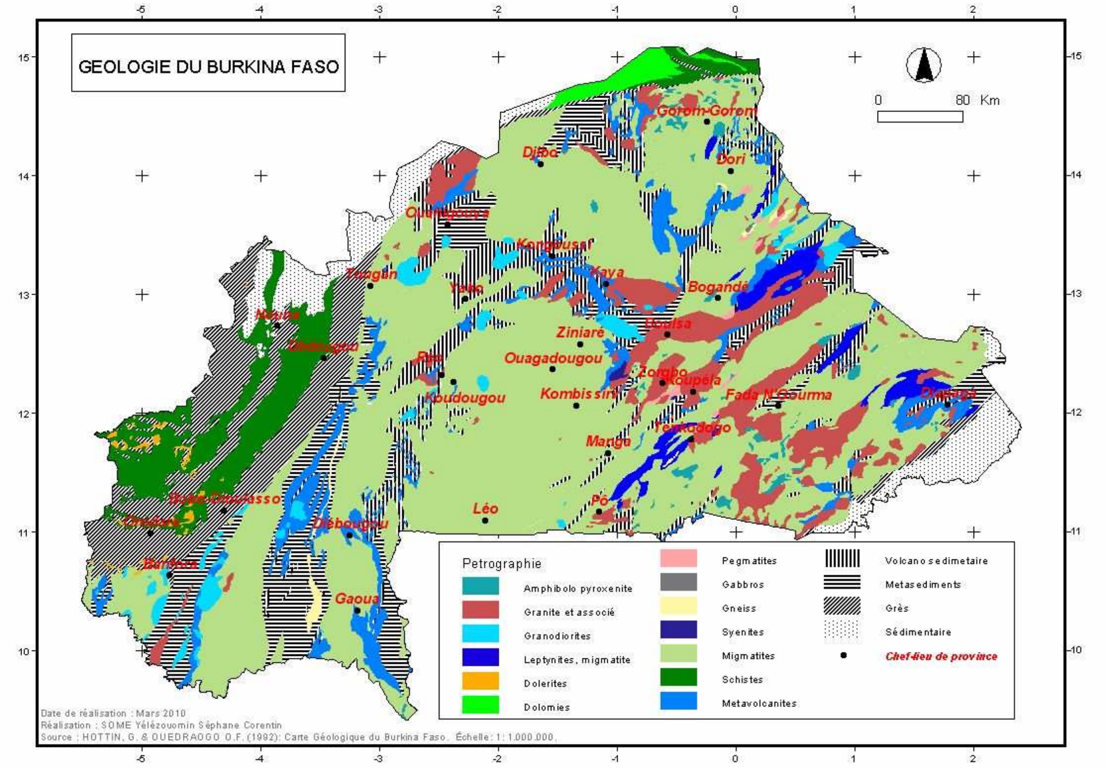
- Rehabilitation of the Toussiana dams and reconstruction of the Lobi dam (could generate an extra 5 Mm3 of available water with the Lobi only). The works required on the Lobi and Toussiana dams have been studied and evaluated in past studies, and the MCA even envisaged funding the works before the idea was finally abandoned. The SN SOSUCO still have the feasibility reports and hope that they will find the funding to rehabilitate the two dams.
- Use groundwater.
- Use surface water stored in the three small lakes located in the area.

Groundwater potential

The geology of the study area is mainly composed of sandstone, volcanic rocks and magmatites. The study area is part of the sedimentary and metamorphosed sedimentary zone of Burkina Faso (SAURET, 2006) and it has one of the highest potential for groundwater in Burkina Faso. Using groundwater as an alternative source of water could therefore be feasible but it would require conducting some geophysical studies in the area to precisely determine the potential of the local aquifers.

If the geophysical study shows that groundwater is a reliable solution and that a well can be drilled next to the main irrigation canal it could be envisaged to build a pumping well were the water would spill over in the main canal of the Karfiguela irrigation scheme. Groundwater would then be used to supplement water abstracted in the Comoé River when it is required.

Figure 8: Simplified geological map of Burkina Faso



Pumping groundwater would generate extra cost due for instance to the use of pumps and the construction of a water distribution system. Cost analyses are therefore necessary for further analyses. A business plan and a willingness-to-pay for water study conducted with farmers could be a possible way of measuring the feasibility of this solution.

Surface water potential

AEDE (2005) estimated that the lakes could provide about 2 Mm^3 and solve part of the water deficit. The Lemouroudou and the Karifugela are fed by drainage water from the Karfiguela and SN SOSUCO fields respectively. The Lemouroudou lake feeds in the Comoé river through a sort of "spill over canal" downstream of the Karfiguela scheme intake and provides water to downstream users including informal farmers located on the banks of the Comoé river. There are no estimates of the amount of water that flows to the Comoé River through the canal.

Of course regular water quality analysis would have to be conducted to ensure that the water from the lakes is appropriate to irrigated rice, sugar cane and moreover vegetables. Ballo

(2010) realised an analysis of the water quality of the Karfiguela Lake and showed that the water could be used for irrigation

Pumping water from these lakes would generate extra cost due for instance to the use of moto-pumps and cost analyses are therefore necessary for further analyses. A business plan and a willingness-to-pay for water study conducted with farmers could be a possible way of measuring the feasibility of this solution. These studies would as well be required to assess the feasibility of supplying water using groundwater. Nevertheless, the SN SOSUCO seems to be the only user having the financial and technical capacity to rely (at least partially) on surface water from the lakes or groundwater for irrigation. This solution would require the SN SOSUCO to either:

- inject the pumped water in the existing pipeline system at the same pressure (10 ATM)
- send the pumped water in the river intakes but the cost of this solution might be prohibitive
- create a separate irrigation system to irrigate part of the sugar cane fields

In the past, the water from the different lakes located within the SOSUCO land was used to irrigate some of the sugar cane fields and supply water to the sugar-transformation plants. At least one of the pumping system still exist and could be used in case of severe drought but the volumes of water stored are very limited (SN SOSUCO irrigation officer personal communication).

4.2.1 Demand management solutions

Demand management solutions will tend to improve the productivity of water. This is the approach adopted by WAIPRO. The rehabilitation of the Karfiguela irrigation scheme should improve the productivity of water by conducting specific actions to improve the irrigation system per se, the production system at the plot level and the organisation in charge of the management of the scheme. The CNID-B (2009) presents the WAIPRO rehabilitation action plan and provides a detailed description of the different actions planned.

Demand management measures could as well be applied to the SN SOSUCO. Roncoli et al. (2009) explains that although the water productivity is already high there are still improvements to be made. The SN SOSUCO is currently trying to improve its water productivity; indeed, about 60 hectares of sugar cane fields are now irrigated through underground drip irrigation. If drip irrigation improves the productivity on these fields, the objective will be to slowly increase the area under drip irrigation. About 600 hectares of sugar cane fields are being irrigated using sprinklers that have a lower productivity, but the SN SOSUCO is reluctant to abandon these sprinklers. Sprinklers allow the SN SOSUCO to reach zones that are difficult to irrigate with other methods. Sprinklers also require a lot of man power compared to other irrigation techniques, maintaining sprinklers is therefore a way of creating jobs.

5. Conclusions

Although there have been several development projects and studies conducted in the area there are still some critical information and data missing. For instance the water available and used by the different water users are not well known. The development of several hydrological models and decision support systems (e.g. the CST and MSSLP) have helped reducing this knowledge gap but more research and monitoring work is needed to fully understand the system.

The rehabilitation of the irrigation system and the improvement of the water productivity of the Karfiguela irrigation scheme will have to be supported by putting in place a monitoring and evaluation system. This system must enable the Karfiguela irrigation scheme to determine their water needs (volumetric and timing) and thus prove they have increased their water productivity. It will allow the Karfiguela scheme farmers to shift from a negotiation based on socio-political arguments to a negotiation based on scientific arguments. This shift will enable the Karfiguela irrigation farmers to negotiate with the SN SOSUCO for specific water quantities based on their agricultural calendar. This shift would be a significant move towards more equal relations between the Karfiguela farmers and the SN SOSUCO.

These efforts towards “rationalised” water allocation decisions could be supported by using a Decision support system. The Comoé Simulation Tool could play this role if it is improved (see section 3.2). A tool to assist the operational management of the dams would be a great asset for the SN SOSUCO and the CLE but the MSSLP still needs to be improved and requires reliable weather/climatic forecast data that, at the moment, do not exist for the study area.

To assist water allocation decision making by the CLE a simple tool providing the water demands and the water productivity of the different users would probably be sufficient. This tool would have to be informed by the results of the monitoring and evaluation systems put in place by the different users (especially the Karfiguela irrigation scheme). The SN SOSUCO is already collecting this data.

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