WATER BALANCE ACCOUNTING FOR LOCATION CHOICE OF NEW SMALL DAMS IN THE PRETO RIVER BASIN IN THE FEDERAL DISTRICT, BRAZIL

Max Linsen, Rijkswaterstaat Centre for Water Management, (Ministry of Infrastructure and the Environment,) The Netherlands
Lineu Rodrigues, Embrapa Cerrados, Brazil
Bert Enserink, Delft University of technology, The Netherlands

ABSTRACT

Decision-making processes in water resources management involve technical, institutional and stakeholder aspects. Choices for suitable locations for new small dams are no exemption in this respect.

Over the last two decades plans have been made for the construction of dozens of small dams in the Preto River basin (PRB) in the Federal District (DF) of Brazil. These dams should improve water availability for irrigation purposes during seasonal water scarcity. This case is well suited to investigate the interaction between the role of models, institutional analysis and stakeholder analysis in decision-making processes.

In the current project a water balance accounting model was being used for the first time, consequently many stakeholders can be involved in public participation processes.

The requirements for locations of new small reservoirs were investigated. What has become clear is the fact that localized research (in addition to system research) into soil type, discharges and actual water use should be combined with institutional requirements. Integration of technical, institutional and stakeholder requirements should result in a location choice.

Key Words: small reservoirs, water balance, WEAP model, Brazil

INTRODUCTION

Water scarcity and droughts increasingly cause problems in semi-arid areas where irrigation is applied. Droughts can be defined as natural phenomena (EEA 2009), where the precipitation deficit is significantly higher than in a normal situation (f(area, time)). When related to irrigation water scarcity could be defined as an anthropogenic phenomenon, in which an overexploitation of a water system leads to an imbalance between water availability and demand.

Small reservoirs or small dams are hydraulic constructions used in some regions in Brazil, sub-Saharan Africa and West Africa to improve water access in semi-arid bi-seasonal regions. Small reservoirs catch water, usually surface runoff, during the rainy or wet season in order to make water available during the dry season (Liebe 2007). They have been constructed by local governments, communities and on private initiative (SRP, 2007).

Small reservoirs are applied as storages for small-scale irrigation purposes in the Preto River basin in the Federal District, Brazil. Irrigation is the main cause of groundwater overexploitation in agricultural areas in many semi-arid areas (EEA, 2010) and is occuring in the Preto River basin. During the last 30 years, local governments have initiated a decision-making process intended to start construction of new small reservoirs. Since the beginning of this millennium, research has been carried out to the technical, institutional and stakeholder environment of small reservoirs (SRP 2003). The evaluation showed that this policy process failed as no new reservoirs had been constructed, while the need for these reservoirs was generally recognized (Balasz, 2009). An increasing demand for irrigated crops, combined with increased durations of drought, determine the need for small scale water storage.

The general context of this study is the impact of small reservoirs on the water balance of the Preto River basin. The specific purpose of this study was finding the requirements for choosing the best locations for new small reservoirs in the sub basin. To address this, three aspect of water management were taken into account: the water balance in the sub catchments, the institutional framework and the stakes of stakeholders involved.

Figure 1 shows the elements relevant to the analysis of a water resources problem and the design of solution directions. The latter will not be subject of this paper though.

The study was carried out in a three stages approach:

1. water balance overview on the scale of the sub catchment, indicating the water management requirements for choosing locations for small reservoirs
2. overview of stakes and interest related to irrigation and small reservoirs locations in the sub catchment
3. inventory of institutional aspects of application of small reservoirs

This staged approach offered the possibility to involve stakeholders in the whole sub catchment in policy making. In addition, laws, policy and organisation interactions were analysed from a water management perspective. And finally, the efficiency of applying small reservoirs was examined based on the water balance.

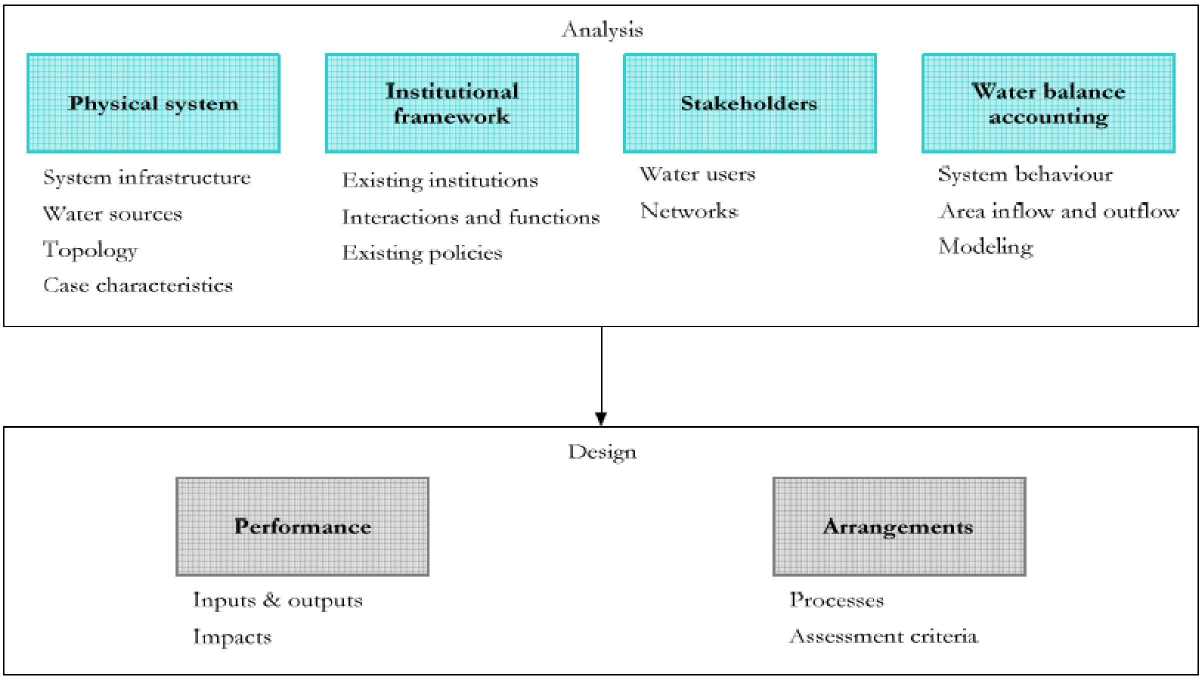


Figure 1. Research set-up

In this paper, we will focus on the role of water balance accounting in the definition of requirements for locations of new small reservoirs (point 1). This resulted in a tool that can be used to assess the possible locations for new small reservoirs

Materials and methods

Water Balance Accounting

The water balance in a (sub)system in a catchment area can be defined as an accounting of all water volumes that enter and leave a 3-dimensional space over a specified period of time (Burt, 1999). Even for a relatively straightforward system, interpreting information related to water supply and water demand is difficult. With a computational water balance accounting program, the balance between a demand-side and a supply side of a water system can be represented (Lévite et al., 2003; Liebe et al., 2007;, Shangguan et al., 2002; SRP 2003; SRP 2007). The demand-side consists of parameters such as agricultural use, industrial use or personal water use. Even pollution and pricing mechanisms can be shared under the definition of demand. The supply side can be described through rivers, creeks, groundwater and reservoirs.

The water balance model used in this study was the Water Evaluation and Planning (WEAP) system (Yates et al., 2005; Lévite et al., 2003; Liebe et al., 2007;, Shangguan et al., 2002; SRP 2003; SRP 2007), in which geo-referenced information can be modelled into a water balance. A screenshot of WEAP with some symbols representing water supply and water demand is presented in Figure 2 below:

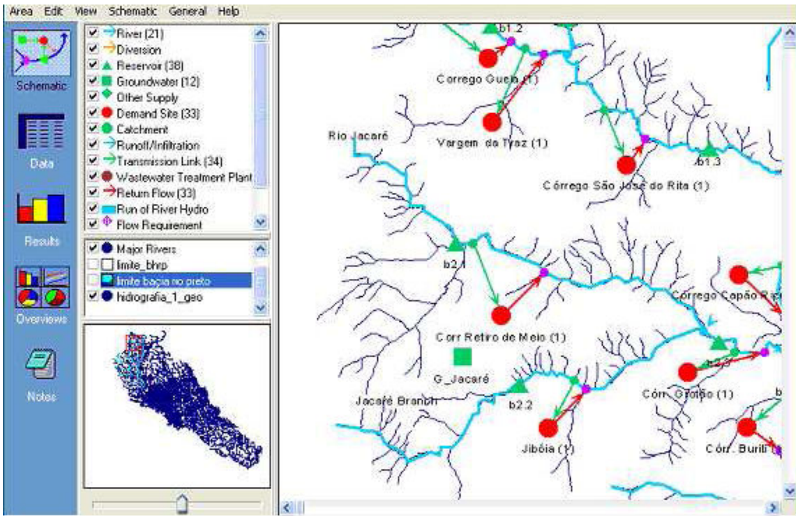


Figure 2. Screenshot of WEAP

System description

The Preto River Basin in the Federal District of Brazil is an area that suffers from periodical drought. It is characterized by a bi-seasonal climate with a dry and a rainy season.
Most stakeholders that are active in the region are farmers or institutional parties related to agriculture and water management.

The Preto river has a length of 378 kilometers, and the basin's area is approximately 10500 km2, 1500 km2 of which lies within the area that was researched in this study (CBH-Paracatu 2005). Other parts are located in the states of Minas Gerais and Goiás.
About 80 percent of all agricultural activity in DF is carried out in this river basin. The river flows into an important tributary of the Sao Francisco river (the third largest river of Brazil) Within the PRB, over 99 percent of all water is used for irrigation purposes (Carneiro, Maldaner et al. 2007). Especially during the dry season, the availability of water for irrigation purposes is uncertain.
The mean annual run-off is 25,65 m3/s, in a catchment area of 1840 km2.

A typical annual runoff curve (with monthly values) for one of the tributaries to the Preto river is presented in Figure 3 below. In total, around 20 tributaries with a comparable curve flow into the Preto river in the area examined.

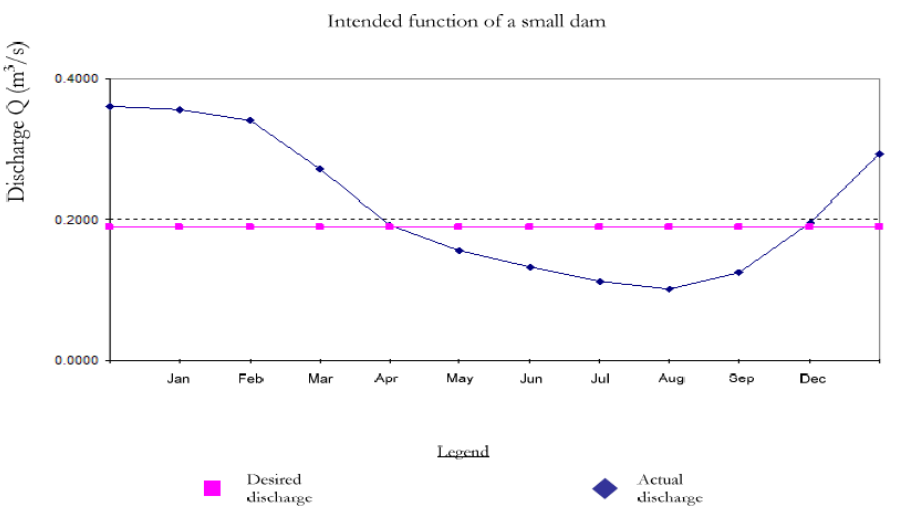


Figure 3. Typical annual runoff curve of Preto tributaries

Modelling small reservoirs in the Preto River Basin

The model was applied in a basic scenario and three alternative scenario's in order to understand the influence of small reservoirs on the water balance.

1. Basic scenario: no intervention by small reservoirs in the system. This scenario represents the unmodified water balance
2. Application of small reservoirs
3. Variation in seasonal conditions (dry years and wet years) to show the efficiency of small reservoirs expressed in water availability
4. Variation in the size of reservoirs to show the impacts of minor system changes

To this end, the following data were incorporated in the model:
Supply data, such as river head flows, monthly average flows, annual average flows
Demand data, such as water use rates, monthly irrigation, and other water demands
Reservoirs characteristics, such as regulated discharges, volume-elevation ratio's, seepage, evaporation, reservoir capacities, locations (density across the area, depending on regulated outflow and distance).
The data were gained through earlier studies carried out in the tributary catchment of the Buriti Vermelho (Dekker and Rodrigues, 2008). Other data (concerning run-offs, planned locations and dimensions of the reservoirs) were provided by the Secretariat of Agriculture of the Federal District, Brasilia, Brazil.
Water demand data were obtained through interviews with the water users and the data mentioned above. Based on these input values, the scenarios were calculated.
Some key modeled outputs would be the extent to which water demands could be met with and without reservoirs, and the amount of water leaving the system. After all, the Preto river is an important tributary to the great Sao Francisco river.

Results

The first and most basic output of this study, was the establishment of a calculated water balance. Before this study was carried out, a decision-making process had taken place related to new small reservoirs, without the information on the water balance. Consequently the influence of small reservoirs had been taken into account, which is the second result of this study.
The influence of small reservoirs based on their location characteristics was mapped. In order to be effective, small reservoirs must respect a minimal distance to head, and depending on the tributaries, a minimal distance amongst each other. Figures 4 a and 4b show the recharge rate (red line) when barriers respect a minimum distance (a) and when they are situated closer to each other (b). The horizontal axes show 24 months. The red line represents the recharge through a virtual net water balance (inflow-minus outflow), under the assumption that the reservoir has to be filled during the first season. The recharge rate suffers from the losses of the dam upstream when situated too closely. The influence as ensembles on the water system in terms of (seepage, evaporation) losses should not be underestimated.
Finally, small reservoirs were presupposed to have a regulatory function (peak shaving), making available water during the dry season that was superfluous

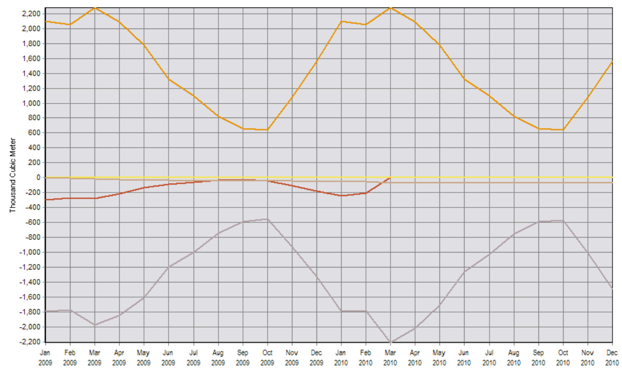


Figure 4a normal reservoir refill rate (red line)

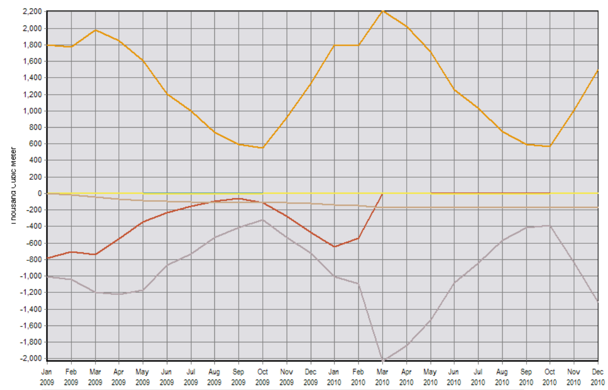


Figure 4b reservoir refill rate when other reservoir is located nearby upstream.

(excess water) during the rainy season. Modelled results showed no such effect.

Application of this water balance model resulted in some relevant criteria for locations of new small reservoirs. The model interface was very suitable for feeding back these criteria to stakeholders. In order to improve the possibility for stakeholders to provide feedback, the model interface was adapted to this specific purpose. This could only be done for a limited number of locations and scenarios within the frame of this project. An example of a stakeholder-interface is provided in figure 5.

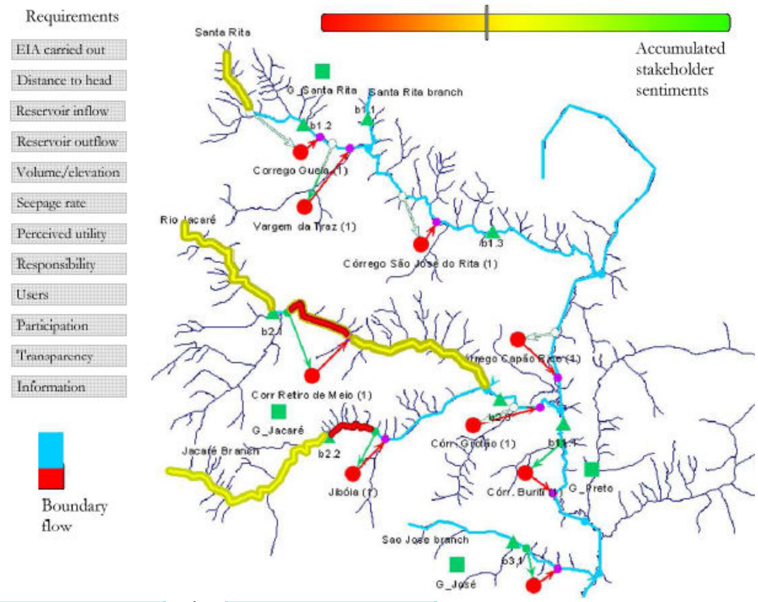
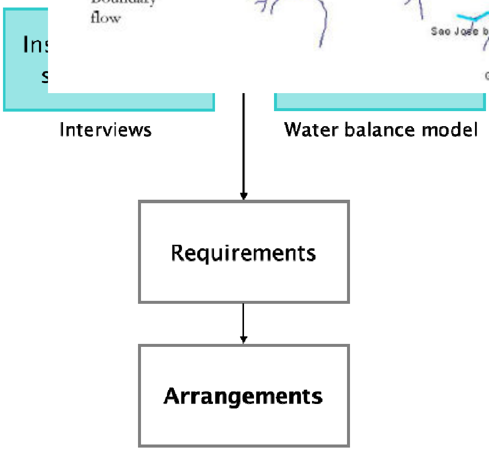


Figure 5: model interface adapted to stakeholder feedback



Discussion

Modelling water balances was carried out here for supporting purposes of a complicated decision-making process. Having a water balance as input for decision-makers and stakeholders, is of added value for the quality of any open policy decision-making process.

Water balance model as a starting point is a merely one aspect of a truly integrative approach, though. The stakeholders and institutional context of a decision-making process should also be incorporated. However, the results of this study show, that the model that was used can also be used as a tool to map stakeholders desires and integrate them with the water balance overview. In that way, the specific goals of this study were met.

Formulating general requirements by means of a water balance accounting model should be complemented by specific technical requirements in the future. To accomplish this, localized research is necessary, for which a comparative method should be designed.

Harvesting feedback from stakeholders based on a water balance accounting model was very promising. The first results should be complemented with further feedback exercises. For this, the adapted model interface showing both model results and stakeholder criteria should be developed.

REFERENCES
ADASA. (2008, 07-01-2009). "Agência Reguladora de Águas e Saneamento do Distrito Federal." from http://www.adasa.df.gov.br/opencms/Adasa/index.html.
Ahrends, H., M. Mast, et al. (2008). "Coupled hydrological-economic modelling for optimised irrigated cultivation in a semi-arid catchment of West Africa." Environmental Modelling & Software 23(4): 385-395.
Alvarez, V. M., M. M. Gonzalez-Real, et al. (2008). "Regional assessment of evaporation from agricultural irrigation reservoirs in a semiarid climate." Agricultural Water Management 95(9): 1056-1066.
Balazs, C. (2005). Rural Livelihoods and Access to Resources in Relation to Small Reservoirs: A Study in Brazil's Preto River Basin. . Energy and Resources Group Berkeley, University of California.
Branco, A. d. M., J. Suassuna, et al. (2005). "IMPROVING ACCESS TO WATER RESOURCES THROUGH RAINWATER HARVESTING AS A MITIGATION MEASURE: THE CASE OF THE BRAZILIAN SEMI-ARID REGION." Mitigation and Adaptation Strategies for Global Change 10: 393-409.
Burt, C., Irrigation Water Balance Fundamentals (1999) Conference on Benchmarking Irrigation Systems Performance Using Waer Measurement and Water Balances. San Luis Obispo, CA. March 10. USCID, Denver, Colo: 1-13.
Carneiro, P. J. R., V. I. Maldaner, et al. (2007). "Evolução do Uso da Água na Bacia do Rio Preto no Distrito Federal." Espaço & Geografia 10(2): 47-76.
Causapé, J., D. Quílez, et al. (2005). "Irrigation Efficiency and Quality of Irrigation Return Flows in the Ebro River Basin: An Overview " Environmental Monitoring and Assessment 117(1-3): 451-461.
CBH-Paracatu (2005). Plano Diretor de Recursos Hídricos da Bacia Hidrográfica do Rio Paracatu, Resumo Executivo, Governo do Estado de Minas Gerais, Secretaria de Estado de Meio Ambiente e Desenvolvimento Sustentável – SEMAD, Instituto Mineiro de Gestão das Águas - IGAM.
Dekker, T., L. N. Rodrigues, et al. (2008). Assessing deep seepage in small reservoirs. CGIR International Conference of Agricultural Engineering. Brazil.
GDF (2001). Projeto de aproveitamento hidroagrícola da bacia do rio Preto no Distrito Federal. Brasília, Secretaria de Agricultura e Abastecimento: 64.
GOLDER/FAHMA, C. (2006). Plano de Gerenciamento integrado de Recursos Hídricos do Distrito Federal - PGIRH /DF. Belo Horizonte. 1.
Jia, Z. and W. Luo (2006). "Modeling net water requirements for wetlands in semi-arid regions." Agricultural Water Management 81(3): 282-294.
Lévite, H., H. Sally, et al. (2003). "Testing water demand management scenarios in a water stressed basin in South Africa: Application of the WEAP model." Physics and Chemistry of the Earth 28(20-27): 779-786.
Liebe, J., Andreini, M., van de Giesen, N., and Steenhuis, T., Ed. (2007). The Small Reservoirs Project: Research to Improve Water Availability and Economic Development in Rural Semi-arid Areas. The Hydropolitics of Africa: A Contemporary Challenge. Cambrige, Cambridge Scholars Publishing.
Maldaner, V. I. (2003). Análise dos conflitos do uso da água na bacia hidrográfica do rio Preto no DF. Brasília, Universidade Católica de Brasília. Master: 121.
Ministério do Meio Ambiente (2006). Plano Nacional de Recursos Hídricos C. N. d. R. Hídricos.
NCA (2002). Relatório de Impacto Ambiental do Aproveitamento Hidroagrícola da Bacia do Rio Preto Sub-bacia do Rio Jardim – Barramento 8.3. Brasília, Secretaria de Meio Ambiente e Recursos Hídricos,.
Queiroz, G. (2005). Justiça pára projeto de irrigação Rio Preto, Barragens exigem licença ambiental do Ibama. Jornal do Brasil. Brasília.
Rodrigues, L. N., A. E. Ramos, et al. (2008). "Aspectos legais a serem considerados na construção de pequenas barragens." from http://www.criareplantar.com.br/artigos/ler/?idArtigo=12632.
Rodrigues, L. N., E. E. Sano, et al. (2007). "Distribuição espacial e área máxima do espelho d´água de pequenas barragens de terra na Bacia do Rio Preto. ." Espaço e Geografia, 10: 101-122.
Rodrigues, L. N., E. E. Sano, et al. (2008). Water Storage Capaity of Small Reservoirs in the Rio Preto Basin, Brazil. CIGR - International Conference of Agricultural Engineering Brazil.
SEDUMA. (2008, 07-01-2008). "Secretaria de Estado de Desenvolvimento Urbano e Meio Ambiente." Retrieved 26-05-2008, 2008, from http://www.seduma.df.gov.br/001/00101001.asp?ttCD_CHAVE=162&btOperacao=.
Shangguan, Z., M. Shao, et al. (2002). "A model for regional optimal allocation of irrigation water resources under deficit irrigation and its applications." Agricultural Water Management 52(2): 139-154.
SRP. (2003). "Small Multi-purpose Reservoir Ensemble Planning, project proposal." from http://www.smallreservoirs.org.
SRP (2007). Annual Report. CPWF Annual Progress Report[Proforma 3], Small Reservoirs Project.
Yates, D., J. Sieber, et al. (2005). "WEAP21 – A Demand-, Priority-, and Preference-Driven Water Planning Model. Part 1: Model Characteristics. ." Water International 30: 487-500.
Zagona, E. A., T. J. Fulp, et al. (2001). "Riverware: A Genenarilzed Tool for Complex River Basin Modeling." Journal of the American Water Resources Association 37(4): 913-929.