Journal of Hydrology: Regional Studies 5 (2016) 213–225

Contents lists available at ScienceDirect

Journal of Hydrology: Regional Studies

journal homepage: www.elsevier.com/locate/ejrh

Evaluation of reservoir operation strategies for irrigation in the Macul Basin, Ecuador

Vicente Tinoco[a,b,*], Patrick Willems[c,e], Guido Wyseure[d], Felipe Cisneros[a,b]

[a] Universidad de Cuenca, Departamento de Ingeniería Civil, Av. 12 de Abril, Cuenca, Ecuador
[b] Universidad de Cuenca, PROMAS, Av. 12 de Abril, Cuenca, Ecuador
[c] KU Leuven, Hydraulics Division, Kasteelpark Arenberg 40, BE-3001 Leuven, Belgium
[d] KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium
[e] Vrije Universiteit Brussel, Department of Hydrology and Hydraulic Engineering, Pleinlaan 2, 1050 Brussels, Belgium

ARTICLE INFO

Article history:
Received 28 April 2015
Received in revised form 21 November 2015
Accepted 28 December 2015
Available online 6 February 2016

Keywords:
Reservoir operation
Conceptual model
Irrigation

1. Introduction

Irrigation projects are conceived for supplying water to agricultural lands where rainfall does not meet the crop water requirements during dry seasons or all year round (Withers and Vipond, 1980). The Macul Basin, located in the central part of the Ecuadorian coastal region (Fig. 1), consists of mainly agricultural lands and relatively small streams. The local economy is based on agriculture, livestock and fishing but these activities are at this moment rainfall dependent. Although the annual rainfall is 2000 mm, 80% of rainfall occurs between January and May. Currently, the crop production is limited to one harvest per year, which is also vulnerable to climate variability. In order to extend the growing season and to reduce the risk of crop failure, an irrigation project is planned for the Macul Basin.

Large irrigation projects aim at positive socio-economic impacts. This requires proper planning of reservoir operation strategies during the preconstruction stage. In deriving strategies an adequate relationship between water required for irrigation and for river environmental flows is attempted (Cai et al., 2003). Usually, reservoir operation strategies are tested by river/reservoir models as part of decision supporting tools for integrated water management (Loucks et al., 2005).

This research focuses on evaluating the reservoir operation management of the irrigation system as planned in the Macul Basin, Ecuador. The aim of our study it to design optimal reservoir operation strategies to reach a sustainable balance between irrigation demands, diverted flows, and respecting river ecological flows released from the reservoirs. For achieving this objective, a conceptual model is built for simulation of the integrated system, and applied in combination with a

* Corresponding author at: Universidad de Cuenca, Departamento de Ingeniería Civil, Av. 12 de Abril, Cuenca, Ecuador.
E-mail addresses: vicente.tinoco@ucuenca.edu.ec (V. Tinoco), Patrick.Willems@bwk.kuleuven.be (P. Willems), Guido.Wyseure@ees.kuleuven.be (G. Wyseure), felipe.cisneros@ucuenca.edu.ec (F. Cisneros).

http://dx.doi.org/10.1016/j.ejrh.2015.12.063

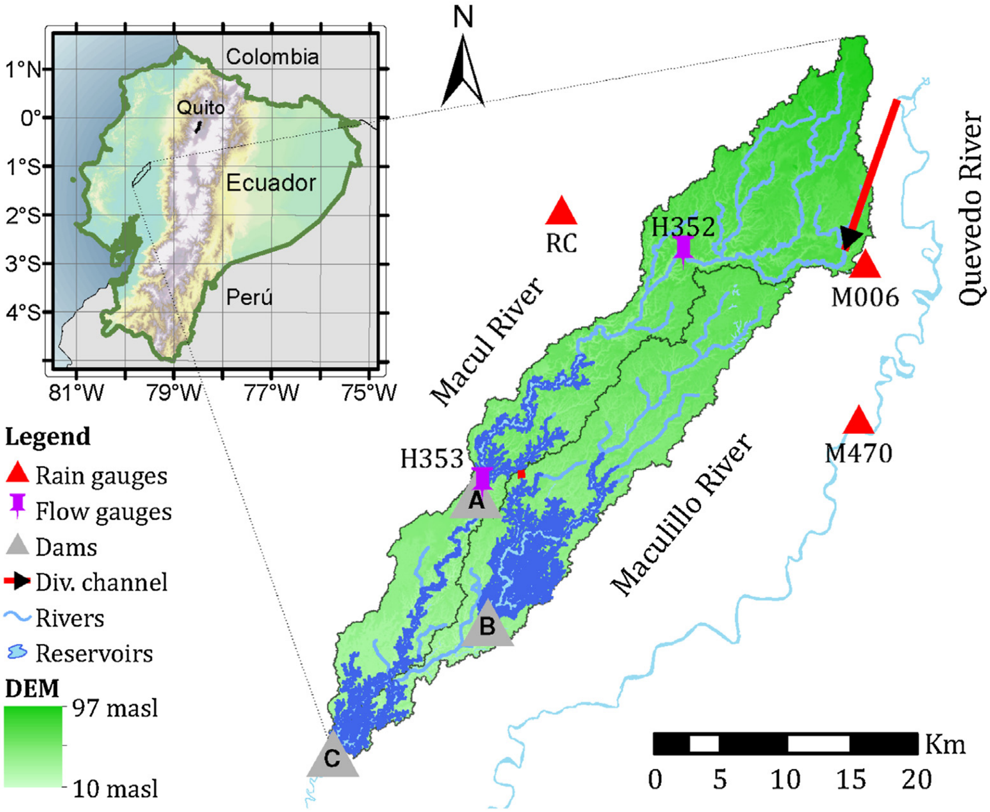

Fig. 1. Map of the Macul River Basin, Ecuador, showing its main components and the irrigation scheme. Reservoirs surface areas are presented at their maximum capacity. Arrows represent the diversion channels.

parameterised method for optimising the reservoirs' operation. In order to account for the long-term climate variability, long-term time series of hydro-meteorological data were used to force the model.

2. Case study and data

2.1. Case study description

The Macul Basin is located in Los Rios Province of Ecuador. It has an area of 604 km^2. Its geomorphology consists of medium hills and flat areas (PLR, 2013). The terrain elevation varies from 10 m to 100 m.a.s.l. The region has one of the warmest air temperatures in Ecuador ranging between 20 and 35 °C along the year. Water resources are abundant during the rainy season from January to May. The drainage system consists of two main perennial streams and several ephemeral tributaries. The main streams are the Macul and Maculillo Rivers, which during extreme rainy seasons have reached discharges up to 70 and 45 m^3/s, respectively; while during the dry seasons those rivers can have discharges below 1 m^3/s. There are approximately 45,000 inhabitants, among which 68% of the economically active persons work on agriculture, livestock or fishing (INEC, 2010; PLR, 2013).

The agricultural potential lands comprise fertile classes of Mollisol and Inceptisol soils, where multiple crops are sown. The crops are classified in short cycle and perennial crops. The short cycle crops are maize, soybean, rice, bean, groundnut, and watermelon. The perennial crops are cacao, banana, and palm. The integrated reservoir system planned in the Macul Basin aims to irrigate thirty thousand hectares of agricultural land. Its irrigation scheme aims distributing the water resources in time and in space along potential agricultural lands for extending the growing periods. For that purpose three detention dams (reservoirs) are planned: one at the upper Macul sub-basin, one at the Maculillo sub-basin, and the last one downstream the junction of the mentioned rivers (Fig. 1). Hereafter, those reservoirs are called A, B, and C respectively. Their features are summarised in Table 1. The total storage capacity of the system is 250 × 106 m^3. PROMAS (2014) determined that the sub-basin contribution to the reservoirs is not enough to fill the reservoirs to maximum capacity during rainy seasons. Therefore, a diversion channel was designed to bring an additional average inflow of 10 m^3/s from the Quevedo River to the Macul River during the first five months of the year. The three reservoirs are connected either by natural streams or by an artificial channel (A–B), with the water flowing in the directions shown in Fig. 2.