Flood Scaling in changes in land cover change Combeima River Basin

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ABSTRACT:

High waters and flows are environmental concerns because of their potential effects to communities established next to the streams. The combined effects of climate change and evolution of land use make challenging the estimation of peak flows. Hydrologic models have been useful to describe the response of watersheds; however, their implementation requires data not readily available in occasions. Moreover, environmental authorities have limited resources to address the requirements of modeling. This work develops two objectives: i) to describe the effect of land use changes in the flow regime, and ii) to introduce scaling into the process of estimating peak flows under land use change scenarios. Hydrologic simulation was conducted in the Combeima River watershed and its response was assessed to land use variations between 1991 and 2012. Results illustrate the potential application of the Power Law to estimate peak flows with minimal simulation requirements.

Key words: *Scaling behavior, flood quantiles, land cover change*

INTRODUCTION

Environmental changes have likely modified the runoff regime and flood behaviour of hydrologic watersheds (Bronstert et al, 2007). Kumar et al. (2008) reports that soils with grassland covers show a lower water retention compared to agricultural or forestry systems; therefore, it can be said that changes in land use can have an effect on the magnitude of peak flows (e.g., Villarini et al, 2009) and may be used as a strategy to reduce the magnitude of floods (e.g., Salazar et al, 2012). In this study, the hydrological response of the Combeima River basin, Colombia, was modelled considering the changes in land use recorded between 1991 and 2007; extreme scenarios, such as grassland and forests as the sole land use in the watershed, were modelled as well. The results obtained show that there is a relationship between land use changes and the magnitude of peak flows. Hydraulic properties of soil were also studied including: the amount of useful water in the soil (soil humidity that regulates evapotranspiration), which will be referred to as static storage (Hu) hereafter; vertical saturated hydraulic conductivity (Ks); horizontal saturated hydraulic conductivity horizontal (Kss); and their relationship with the magnitude of peak flows. It was found that this relationship has a scalable behaviour. Later, a frequency analysis was performed to analyse the behaviour of the probability distribution parameters. This results of this research were reported in detail by Peña et al (2016).

METHODOLOGY

Distributed hydrological modelling with TETIS model (Frances et al, 2007) was used to assess the response of the Combeima River basin to land use changes in the years 1991, 2000, 2002 and 2007. Two modelling scenarios were also assessed considering different land uses: one for grasslands as the only land use in the basin and one for forests as the sole land use. The modelling exercise required daily precipitation records between 1971 and 2012 from nine climatic stations, and flow records from one hydrometric station. Furthermore, maps of Hu, Ks, and Kss were generated to evaluate the effect of their variation on the flow behaviour of the basin.

The non-parametric test of Mann-Kendall (Mann, 1945; Kendall, 1975) was applied with the objective of detecting trends in the time series of flows, temperature and precipitation as indicators of climatic variability. Later, a simple scaling in the relationship between flow and Hu, Ks, and Kss was implemented. A general framework for the distribution of peak flows was introduced by Gupta and Waymire (1990), while the theory of simple scaling has been applied to peak flows in watersheds by Morrison and Smith (2001).

Afterward, to determine the relationship between the probability of occurrence of a peak flow and its period and magnitude, a frequency analysis of maximum flows was performed with the GEV method and the Gumbel probability distribution function (pdf). Parameters of the probability distribution functions were estimated using the maximum likelihood (ML) approach and the best fit was the GEV (Figure 1).

RESULTS

The applied methodology is described in Section 2, while the results for modelling of land use changes and trend tests are presented in Section 3.1; simple scaling of the relationship between peak flows and Hu, Ks, and Kss is presented in Section 3.2.

Land cover /use changes and hidrological modeling

The Mann-Kendall test was used to detect trends in the hydro-climatic series. No trends were detected for the precipitation and temperature historic records, and a negative trend was detected for daily flows. Therefore, the detected trend in daily flows should be attributed to the historical land use changes.

The hydrological modelling of the land use changes was carried out based on maps of the Combeima River basin from the years 1991, 2000, 2002 and 2007. Subsequently the quantiles of the series was obtained. It was observed that the peak flow is high for low Hu values and is lower for higher Hu values (Figure 1).

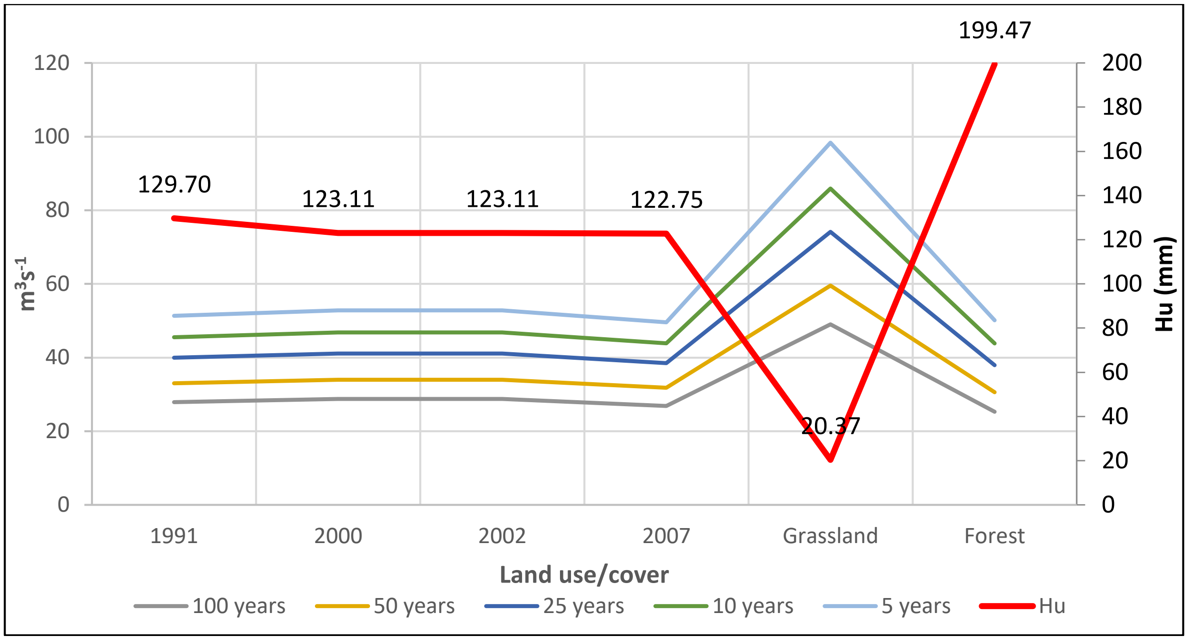

Figura 1 Relationship between annual peak flow quantiles and the static storage (Hu) along time

Simple scaling behavior

The results of the model of land use change in the Combeima River basin were useful to verify the broad simple scaling presented in Equation 1, by verifying the linearity of log (mr) versus log λ for each r, and the linearity of the slope change of r trend to $r\,n$ (Figure 2).

$$\log E[Y^{r}_{\lambda}] = r\,n \log \lambda + \log E[Y^{r}_{1}] \qquad (1)$$

where n is the scale exponent, λ is the spatial factor scale (λ>0), and $E[Y^{r}_{\lambda}]$, are the finite moments of r order. The broad simple scaling for the relationship between peak flow and *Hu*, *Ks*, and *Kss* could thus be verified (Figure 2).

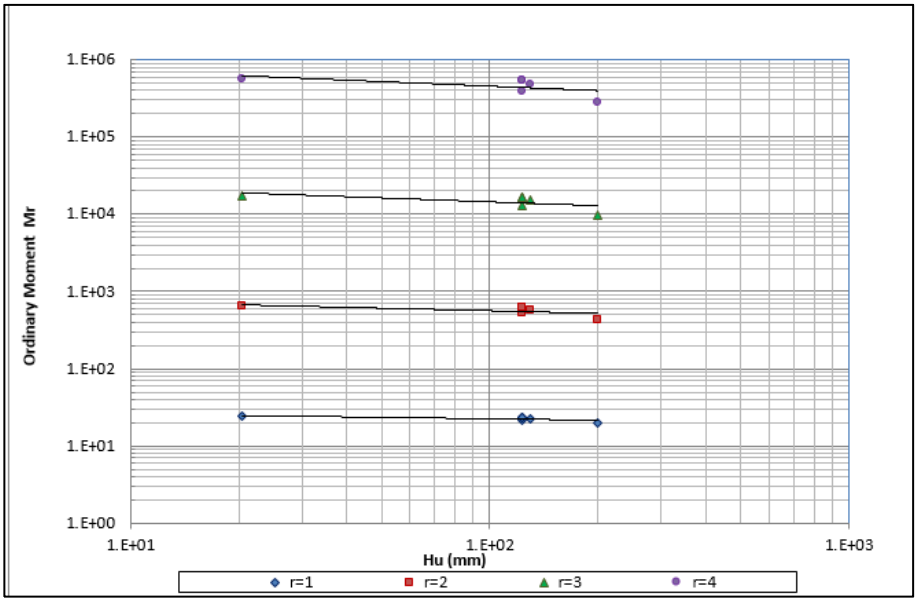

Figura 2 Scaling behaviour of ordinary moments Mr as a function of static storage Hu

CONCLUSIONS

Considering Figure 1, it can be stated that changes in land use in the Combeima River basin influence the magnitude of peak flows, as reported by Ghaffari et al. (2009) and Hernández et al. (2000). Land use changes are also a source of non-stationarity in the flow time series, as shown by the application of the non-parametric test (Mann Kendall). It was also found that floods have a direct relationship with the hydraulic properties of soil; particularly, a relationship between peak flow and *Hu*, *Ks*, and *Kss* was found for each of the modelled scenarios of land use change.

Figure 2 presents the verification of the broad simple scaling described by Equation 1 for *Hu*, *Ks*, and *Kss*.

Finally, a trend was found for the behaviour of the pdf parameters associated with the relationship between peak flows and changes in *Hu*, *Ks*, and *Kss*, which in turn are associated with changes in land cover / use.

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