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The impact of rainfall and land cover changes on the flow of a medium-sized river in the South of Brazil

Jorge A. Martins[a]*, Veronika S. Brand[a], Maurício N. Capucim[a], Carolyne B. Machado[a], Daniel G. Allasia Piccilli[b], Leila D. Martins[a]

[a]*Federal University of Technology - Paraná, Pioneiros Avenue, 3131, 86036370, Londrina - PR, Brazil*
[b]*Federal University of Santa Maria, Avenida Roraima, 1000, 97105-900, Santa Maria - RS, Brazil*

Abstract

Due to the complexity associated to the atmospheric global circulation models and because they operate globally, with resolutions involving hundreds of kilometers, they are not suitable to represent small-scale processes, such as precipitation, which is a fundamental variable to hydrological modeling studies on medium-sized basins. In addition, even studies based on regional models have showed difficulties in representing precipitation during summer months, mainly due to the higher occurrence of extreme events. Otherwise, hydrological models have a greater chance of success in evaluating the local impact of future scenarios of climate change as well as changing conditions of land use and land cover. This study analyzed the occurrence daily flow rates at two stations located in the Ivaí River Basin in Brazilian state of Paraná. It was examined whether there is a change of trend for flow measurements in recent years compared to the first decades of the data series. Historical rainfall series were analyzed in order to verify if the pattern of rainfall in the basin follows the trends observed for the river flow. In relation to rainfall data it was observed that the average annual rainfall slightly increased and the percentage of rainy days significantly decreased, indicating that the rain events, on average, increased and concentrated in a shorter time, explaining the observed increase in extreme rainfall events (events with rates above 80 mm.day-1). A hydrological model was applied in order to verify the role of land cover changes on the observed stream flow trends. The hypothetical scenarios consisted of replacing the current land covered by crops, pasture and original forest. The only significant change in the stream flow was observed for the forest-recovered scenario. In this case, the results indicated a strong reduction in the flow when compared to the current scenario, which is consistent with many recent studies, but not consistent with the trends observed in recent decades in the Ivaí River. This result suggests that a causal relationship between the observed streamflow trends and land cover changes are open to interpretation and need complementary studies.

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* Corresponding author: Tel.: +55-43-3323-1133; fax: +55-43-3315-6121
E-mail address: jmartins@utfpr.edu.br

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1. Introduction

The change in river streamflows is a subject of great concern worldwide, since the vast majority of countries have a significant portion of their economies depending on the warranty of water flow on its rivers. Water supply, irrigation, fishing and power generation are the economic sectors most dependant on streamflows. Some regions worldwide have been benefited by the increase in streamflow. On the other hand, there are regions suffering serious socioeconomic and ecological impacts with the reduction in streamflow. The fact is that the hydrologic systems change in response not only to natural variability of the Earth system, but also to human forces acting within the river basin [1], including land use and land cover changes, water supply, irrigation systems, infrastructure for electricity generation, and global warming. The issue has been discussed by a number of studies, with the vast majority focusing on rivers located in colder regions of the Northern Hemisphere, where the presence of snow is frequent in winter [2]. Most studies call attention to the effects of natural and human-induced land cover changes and climate fluctuations on streamflow [3, 4]. The attribution of causality to human actions as responsible for a significant part of the changes in river flows have found support in many of the studies [5]. Some results have shown that up to 50 % of trends in streamflow over the last half of the 20th century were human-induced [2, 6].

The findings of studies evaluating the effect of land cover changes on river flows suggest that the annual streamflow increase by the reduction in vegetation cover [7, 8], a conclusion valid to any type of forest [7] and for different regions [9, 10]. Changes in the mean annual evapotranspiration rate are the main cause for the streamflow changes attributed to land cover changes. In this case, areas covered by forest have higher evapotranspiration than non-covered areas [11]. Rainfall interception, net radiation, advection, turbulence, leaf area and plant-available water capacity are among the key elements that control the evapotranspiration [12]. Land use changes attributed to agricultural activities, for example, has been suggested as the cause for observed trend of increasing streamflow. The explanation lies in the fact that the conversion of perennial vegetation to seasonal crops have reduced evapotranspiration and increased the amount of streamflow provided by groundwater (baseflow) [13]. There are findings of studies suggesting that climate effects are dominant in annual streamflow, while land-cover changes influence seasonal streamflow. In this case, more (less) forest cover reduces (increases) streamflow in the wet season and increases (reduces) in the dry season [14].

When climate fluctuations are the focus of the studies, the results suggest changes in temperature and rainfall as the cause for the observed annual streamflow trends. For cold regions, a shift toward earlier runoff has been observed in the last century, which have been attributed to seasonal shifts in runoff in response to higher winter and spring temperatures [15, 16], with more rain instead of snow and earlier snowmelt [17]. In terms of the potential effects of climate change on water resources, as simulated by the use of downscaled climate scenarios, the results are quite diverse. In some studies the results have shown a slightly decrease of the basin-average annual precipitation and a significant decrease in annual runoff [18]. Some hydrological projections under climate change in the near future (increasing temperature and large spatial and temporal variability in precipitation) revealed increase or decrease in runoff, depending on sub-regions considered [19]. Climate projections using general circulation models (GCMs) have been applied to assess the hydrologic sensitivity to climate change of large river basins. In general, the results suggest a reduction in annual streamflow for the tropical and mid-latitude basins and an increase for the high-latitude basins [20].

Although it is well established that natural and human-induced forces change the annual runoff, only a few studies have focused on South American rivers. Particularly, the few studies involving historical streamflow annual series for South América are not conclusive, which makes the future of the region surrounded by great uncertainty [21]. The main goal of this study is to analyze the behaviour of stream flow at two stations located in the Ivaí River Basin in the Brazilian state of Paraná. It was examined whether the observed stream flows show any signal of change in recent decades compared to the first decades of the data series. Historical rainfall series were also analyzed in order to verify if the pattern in the river flow follows the trends observed for the rainfall. A hydrological model was applied in order to verify the role of land cover changes on the observed flow trends.