Land use change effects on catchment streamflow response in a humid tropical montane cloud forest region, central Veracruz, Mexico

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Abstract

Tropical montane cloud forests (TMCF) are recognized for their capacity to maintain high dry-season baseflow, and a host of other, ecosystem services. Despite their importance, they are endangered with a multidirectional array of land use changes, including conversion to pasture and crops such as coffee, while there are places where forest is being recovered. However, little is known about the effects of this complex dynamic on catchment hydrology. We investigated the effect of land use on rainfall-runoff response in five neighboring headwater micro-catchments in central Veracruz, Mexico, by comparing primary TMCF (PF), young (20 yr-old) and intermediate (40 yr-old) naturally regenerating TMCF (YF and IF, respectively), shaded coffee (SC), and an intensively grazed pasture (IP). We used a 4-year record of high-resolution rainfall and streamflow (10 min) data, collected from 2015 to 2019. These data were analyzed via hydrologic metrics and statistical tests. Results showed no statistical difference in the regulation capacity of high flows after 20 years of natural regeneration, compared to the PF. In terms of baseflow sustenance, our results suggested that PF and IF better promote this hydrological service than the other land uses, although all the catchments showed high mean annual low flows. SC exhibited a high capacity to modulate peak flows comparable to that of PF, and an intermediate capacity to sustain baseflow, suggesting that the integrated functioning of this catchment was largely preserved. Finally, we found that 40 years of pasture management can decrease the soil hydraulic properties in the area, causing a fivefold increase in the peak discharge response, and a much lower baseflow maintenance compared to PF.

Acknowledgments

We thank the landowners of the micro catchments for permitting us to work on their land. We would also like to thank Carlos Lezama and Víctor Vásquez for their great help in the field. Finally, we appreciate the valuable comments of Friso Holwerda and Juan Von Thaden-Ugalde. This research was founded by a US National Science Foundation Award Number: 1313804. This National Science Foundation grant has been awarded to the University of New Hampshire with a subcontract agreement with Michigan Technological University.

Authorship

Leonardo Sáenz contributed on a regular basis to the analysis and interpretation of the datasets, he made special contributions to the analysis of topography and the integrated interpretation of the results in the context of cloud forest environments. He was involved in drafting various parts of the manuscript, across multiple revisions and countless suggestions to improve the quality of the document.

Alex Mayer participated in the conception and experimental design, he guided and coordinated the acquisition and interpretation of data for 4 years; he was key in drafting the manuscript and revising it critically for important intellectual content across numerus weekly meetings.

Lyssette E. Muñoz-Villers gave suggestions to collect streamflow data, including using salt dilution methods for the calibration of the stage discharge relationships, she also contributed to the definition and analysis of hydrologic metrics and storm indices. She was involved in revising the document critically for important intellectual content, particularly in terms of the dominant hydrologic processes of the cloud forest environments in Mexico.

Heidi Asbjornsen participated in the conception and experimental design; she was also involved in revising the manuscript and adding important intellectual content in terms of the comparison of forest ages and the definition of the novelty aspects of this work, she also contributed to better contextualize this work.

Z. Carter Berry participated in the experimental design and leaded the acquisition of data for 2 years, he also collected and shared data from the vegetation characteristics in the study region. Carter was involved in revising the document critically for important intellectual content, a special contribution was the drafting of the description of the land covers management.

Nathaniel Looker contributed in the acquisition and interpretation of soil data in the study region, he also participated in to the revision of the statistical methods. While writing the manuscript he provided critical feedback, especially in terms of the importance of forest regeneration processes in the study area and the effects of shaded coffee management on soil's degradation.

Robert Manson participated in the conception and experimental design, he always provided support and ideas to navigate problems in the field; he was also involved in the revision of the manuscript and shared previous research publications conducted in the study region, one of his important intellectual contributions to this work was to link the results of this research to make recommendations to payments for environmental services programs.

León Rodrigo Gómez Aguilar participated in the field collection and post processing of rainfall and streamflow data.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon request.

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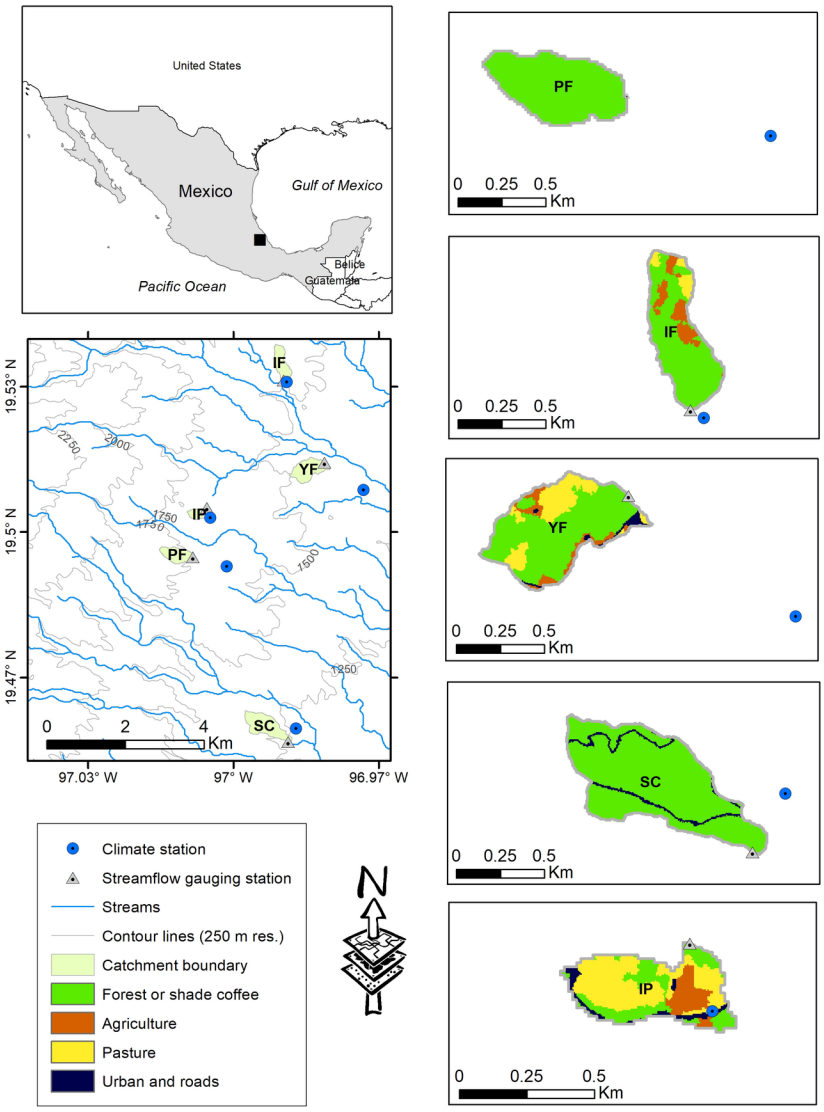

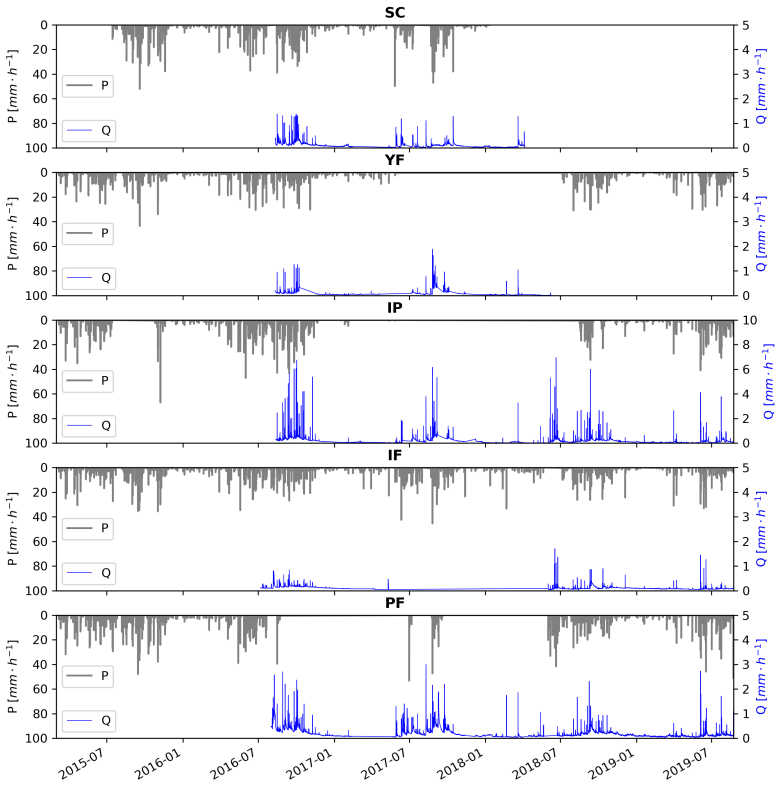

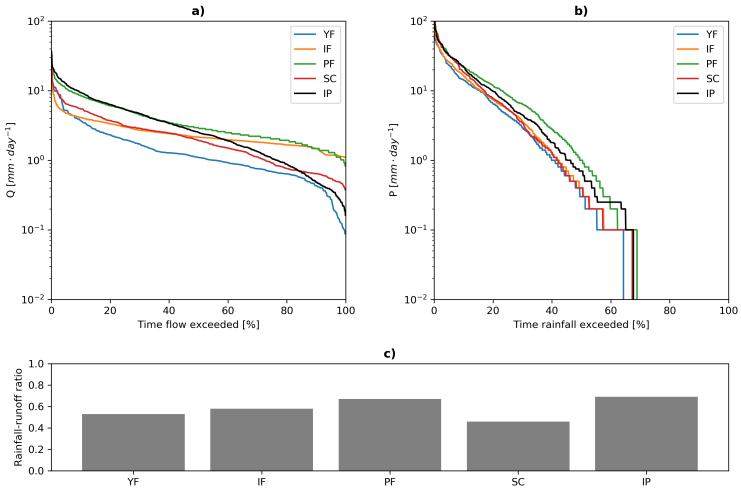

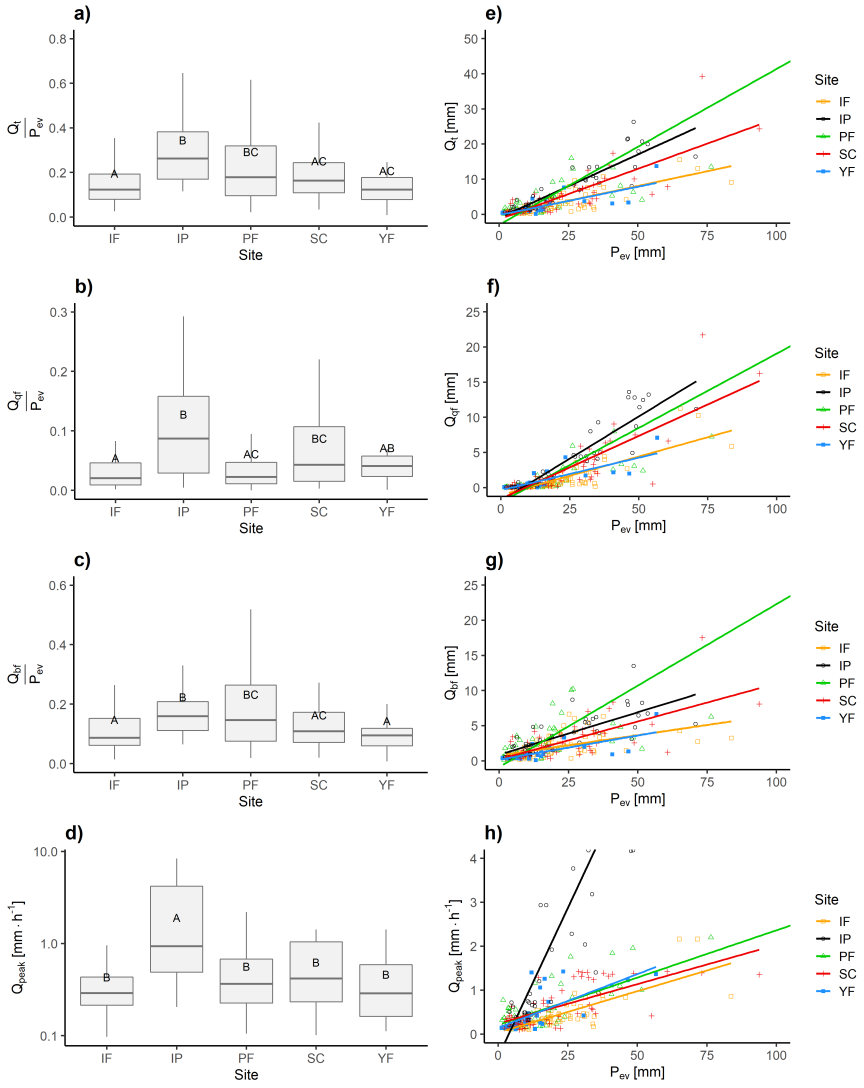

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