# IMPACTS OF MID-TERM CLIMATE CHANGE ON WETLAND AND FLOODPLAIN DYNAMICS: A CASE STUDY IN THE MAGDALENA RIVER BASIN

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Riverine floodplains and wetlands are ecosystems of high biodiversity and productivity, providing numerous benefits: stable water supply, support for fisheries, flood risk mitigation, carbon and nutrient regulation, and improved water quality. Functional floodplain ecosystems depend on hydrologic dynamics—from local- to basin-level—to sustain key physical and ecosystem processes, including episodic lateral and vertical connectivity; habitat heterogeneity; transport and deposition of nutrients and organic matter; recharge of the water table; recruitment, dispersion, and colonization of plants; fish migration triggers; and access to soil moisture. Climate variability is a major factor controlling hydrologic dynamics of floodplains; under climate change, intensified variability (in terms of the magnitude or severity of extreme wet, dry, hot, and cold events) can induce large changes in floodplains dynamics, affecting their capacity to sustain ecosystem processes and the benefits they provide. Here, we present a case study of the effects of predicted mid-term climate change on hydrologic variability of a floodplain system. Our study area is in the Mompós Depression Wetlands, a 3400 km$^2$ floodplain complex in the Magdalena River Basin (MRB) (Figure 1). The MRB comprises about 25% of Colombia's territory between the Central and Eastern Andes. The system hosts over 226 native fish species [1], including at least 16 that migrate for reproduction from the low floodplain to the foothills of the Andes [2]. System dynamics are controlled by both local hydrologic processes, associated with fluvial morphology and topography that determine the connectivity of rivers and floodplains, and by inflows from the upstream tributary basin of approximately 2 x 10$^5$ km$^2$. We evaluated the changes of the hydrologic dynamics as Eco-deficits and Eco-surpluses [3] of seasonal storage events associated with migratory fish ecology. Our results indicate that the compound effect of the changes in precipitation variability (characterized by amplified events at the tails of the distribution) and increased temperature will induce large deficits of seasonal water storages in the floodplain during regular to dry years, and larger flooding events during extreme wet conditions. Figure 2 summarizes the methods used in this work.

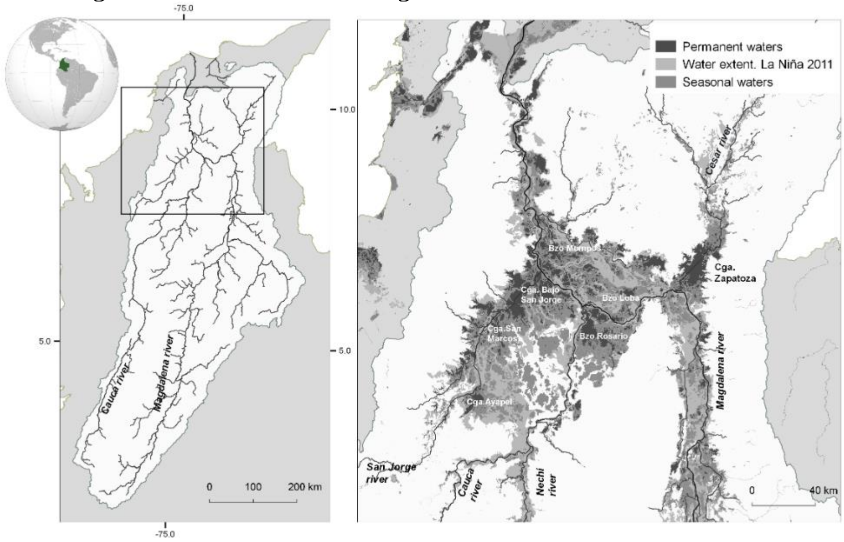


Figure 1. (Left) Magdalena River Basin (MRB) in Colombia. (Right) Floodplain sub-units in the lower MRB.

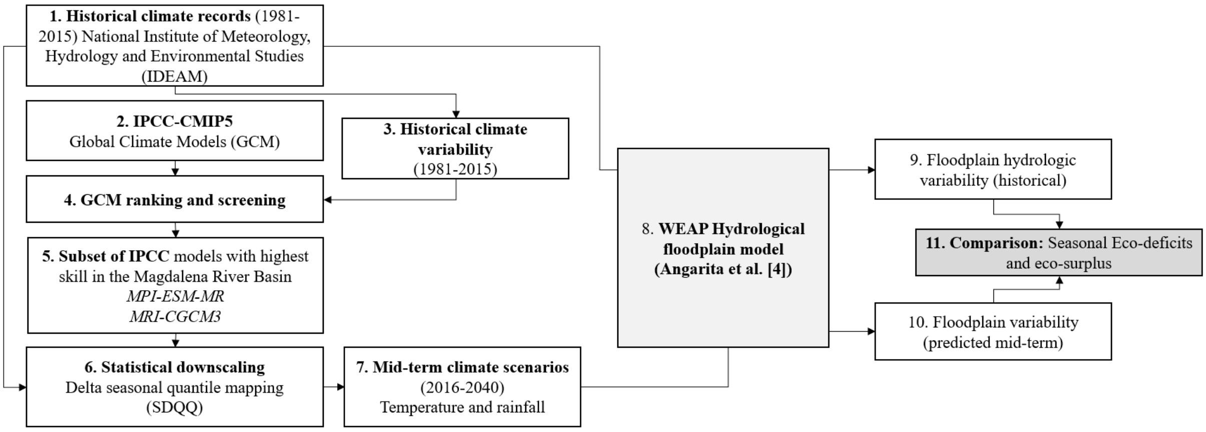


Figure 2. Experimental design to quantify the changes in hydro-climatologic response of floodplains in prospective climate change scenarios in comparison to observed climate variability.

## 1 CLIMATE CHANGE SCENARIOS

Future climate characterization of the Magdalena-Cauca basin included the results of prospective simulations (for the 2015-2040 horizon) of the prioritized global circulation IPCC-CMPI5 models GISS- E2-R, MRI-CGCM3, and MPI-ESM-MR, for RCPs 4.5 and 8.5. Climate models were prioritized based on their capacity to capture long-term historical (observed) climate variability attributes in the period 1981-2005, including: (i) annual total rainfall; (ii) 95th percentiles of daily precipitation; (iii) maximum number of consecutive wet days; and (iv) maximum number of consecutive dry days. The comparison was carried out both for the grid points of the circulation models within a domain that covers the vast majority of Colombian territory, and for the set of grid points that intersect the Magdalena-Cauca macro-basin. For analysis at the inter-annual scale, simulation results of the circulation models were evaluated for: (i) the power spectra of their time series; (ii) correlation coefficients between the maximum number of consecutive dry days per year and the first spatio-temporal oscillation modes of the Indo-Pacific and tropical Atlantic oceans; and (iii) percentages of the temporal variability of the anomalies of annual total precipitation, maximum duration of wet periods and maximum duration of dry periods explained by a moving average of 4 years, associated with the frequency of occurrence of the warm phase of the El Niño-Southern Oscillation phenomenon. Finally, on an intra-annual scale, seasonality (annual cycles of precipitation) of the simulation results was compared with historical observations at the level of regional signals and at the station level. A seasonal quantile mapping Delta Method (SDQQ) and k-Nearest Neighbor (K-NN) downscaling techniques were applied and tested. The best performing downscaling method was SDQQ (Figure 3).

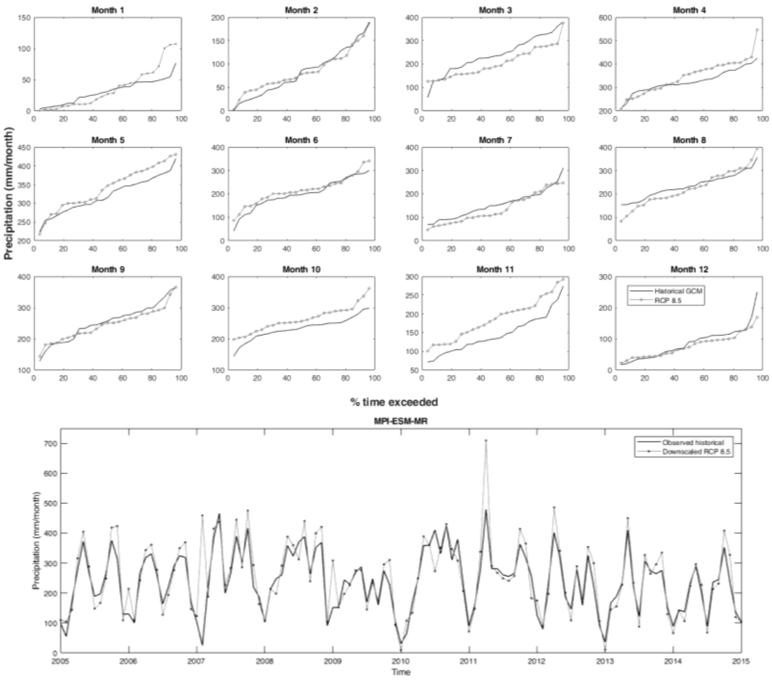


Figure 3. Sample outputs of seasonal quantile mapping methods used to derive GCM-informed mid-term prospective climate scenarios. (Above) Seasonal changes in magnitude of precipitation events of different exceedance time for a given GCM (MPI-ESM-MR). (Below) Resulting time series (10-yr sample shown) of applied seasonal quantile deltas to the historical record.

## 2 MODELLING HYDROLOGIC DYNAMICS

We used the Water Evaluation and Planning (WEAP) model reported by Angarita *et al*. [4]. The model dynamically simulates evapotranspiration, surface runoff, sub-surface runoff or interflow, and deep percolation at the sub-basin level, as well as bi-directional water transfer between rivers and wetlands. The water balance is defined using a semi-distributed approach that reflects topological relationships between catchments, stream networks, and wetlands. The model allows for the evaluation of hydrologic dynamics associated with alteration in the upstream flow regime, climate variability and change, and impacts of upstream hydrology. Sample output is shown in Figure 4.

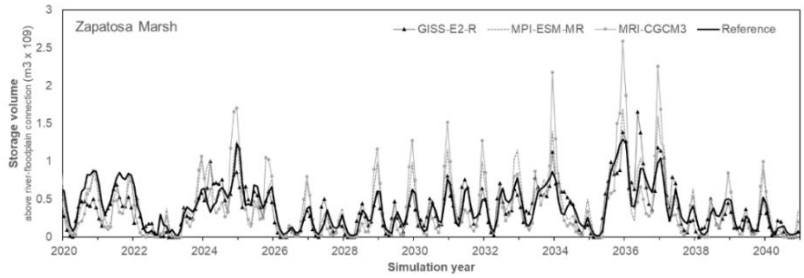


Figure 4. Sample outputs of floodplain simulation using the WEAP model.

We employed seasonal “Eco-deficits” and “Eco-surpluses” (EDS), defined as relative changes of flow duration curves, to assess the impact of variations in the hydrologic regime of wetlands storage. We divided the year into four seasons: Subienda, Bajanza I, Mitaca, and Bajanza II [3]. These periods are based on their biologic and hydrologic relevance in the basin, in particular to fish migration [5]. We differentiated ranges of duration corresponding to storage magnitude for: extreme high (percentage of time exceeded <10%: Max to P10), seasonal (P10 to P75), low (P75 to P90), and extreme low (P90 to Min) flows relevant to diverse ecological processes [6].

## 3 CONCLUSIONS

We explored the effects on floodplain dynamics of changes in climate variability in the MRB over monthly to decadal scales. In the selected IPCC-CMIP5 models, climate scenarios are characterized by amplified variability during drought and extreme wet periods in comparison to the historical reference period. Reduced precipitation and increased temperature reduce floodplain storage volumes during dry to extremely dry conditions (corresponding to quantiles 75 and higher), across all seasons (Figure 5). Deficits of water storage during extremely low and low storage events likely impact several ecological processes such as reptile reproduction, propagation of riparian vegetation communities, and nutrient and organic matter storage, as well as reduce productivity of key migratory fish species due to increased predation.

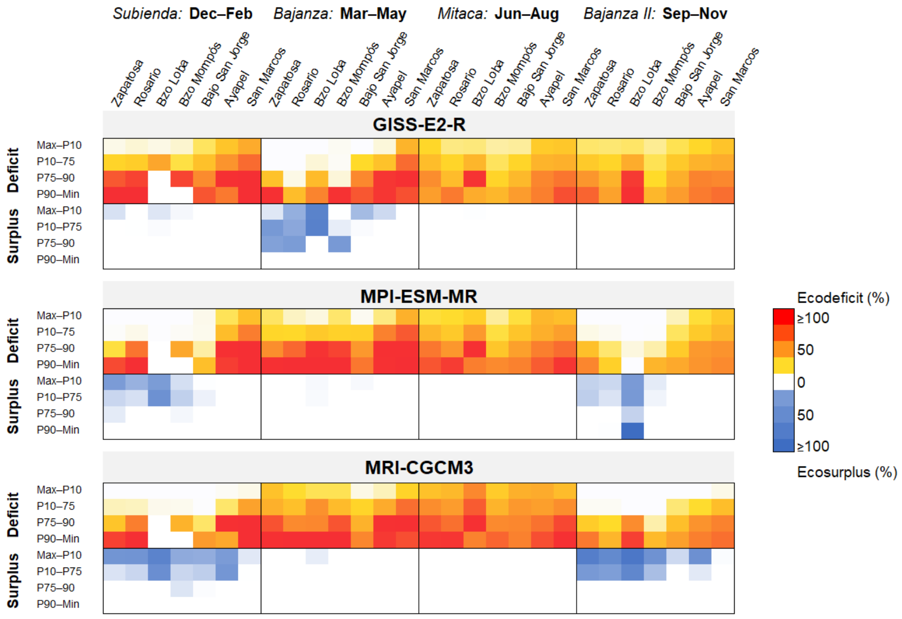

Figure 5. Impacts of climate change scenarios on wetland dynamics—expressed as Eco-deficits or Eco-surpluses.

Likewise, in all the considered scenarios, the model predicted an increase in the magnitudes of seasonal and extreme high flows events for all scenarios (Percentiles 75 and lower, Figure 5). However, timing varied across the year for different climate models, with the GISS-E2-R model increasing the magnitude of extreme wet events during Bajanza I (downstream migration), while MPI-ESM-MR and MRI-CGCM3 increased such events during Subienda (upstream migration) and Bajanza II (second downstream migration). Changes in timing and magnitude of high flows can affect sedimentation, floodplain nutrient and organic deposition, water table recharge, and geomorphologic system dynamics, as well as increase flood hazards for multiple local communities.

## 4 ACKNOWLEDGMENTS

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